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2010

# **Implicit Learning of Spatial Context in Adolescents and Adults with Autism Spectrum Disorder**

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Thesis submitted for the Degree of Doctor of Philosophy

Durham University, Department of Psychology



*DEDICATION-? F???OS?*

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*To Manolis,*

*...and to his mother, Foni!*

—

*St?? ? a????,*

*...?a?st? μ?t??a t?? F????!*

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## ABSTRACT

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The aim of the current thesis was to investigate whether individuals with Autism Spectrum Disorders (ASDs) who show good visuospatial abilities, such as superior processing of local structures (Happé & Frith, 2006; Mottron, Dawson, Soulières, Hubert, & Burack, 2006), may also show intact or even superior learning of visuospatial information. In a series of experiments, with adolescents and adults with ASD and a comparison group of Typically Developing (TD) individuals, learning of spatial context was investigated using a visual search task, known as *contextual cueing* (Chun & Jiang, 1998). Contextual cueing refers to faster target detection in a visual search task with repeated exposure to a visual configuration (context), compared to configurations presented only once. Experiments 1 to 3 indicated that implicit learning may be reduced in ASD, however explicit learning was found to be preserved in ASD. In Experiments 4 to 6 implicit learning was re-examined. Results showed that when attention was oriented to the local parts of the display, individuals with ASD showed superior but atypical implicit learning of context relative to TDs (Experiment 4). However, when attention was directed to spatially distant, non-local contexts, performance was no different than for TD individuals (Experiment 5). Experiment 6 revealed superior implicit learning of local context in ASD and superior implicit learning of global context in TD individuals. Finally, Experiment 6 supported the view that contextual cueing is a local processing task, since both groups attended to local cues for longer periods of time. It is concluded that individuals with ASD show preserved or even *superior implicit learning* under conditions that involve attention to the local patterns.



## 1. GENERAL INTRODUCTION

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### 1.1. Setting the Scene

In everyday life, people learn about the structure and regularities of their complex environment, without necessarily intending to do so, and in a way that this acquired knowledge is difficult to express. This type of learning, known as implicit learning, is thought to mediate language learning and the acquisition of motor and social skills (Cleeremans & Dienes, 2008; Meltzoff, Kuhl, Movellan, & Sejnowski, 2009; Perruchet, 2008). For instance, learning the grammatical rules of a language, learning to type without looking at the keyboard, or developing expertise in domains such as social judgments, are processes that typically involve lack of intention and a difficulty in describing exactly how learning occurred. The purpose of this thesis is to investigate one form of implicit learning that relates specifically to learning of spatial context in individuals with ASD.

The importance of studying implicit learning in autism lies firstly in the fact that it is probably the most common way that we acquire knowledge in everyday life, and secondly that there are very few studies of implicit learning in autism, while none of them has specifically examined ASD individuals in adolescence and adulthood. Indeed, when the work for the present thesis began in 2004, there were only two publications on implicit learning in autism (Klinger & Dawson, 2001; Mostofsky, Goldberg, Landa, & Denckla, 2000) and even today little is known about its development and maintenance beyond childhood, although in typical development implicit learning of spatial context in particular is known to mature with age (Vaidya, Huger, Howard, & Howard, 2007). The present thesis constitutes the first

## General Introduction

demonstration of implicit learning of spatial context in adolescents and adults with autism and average or above average IQ (intelligence quotient).

The lack of research that specifically addresses implicit learning in autism has meant that our understanding of this process is very limited. Currently, the general view of how people with autism learn, which seems to coincide with Leo Kanner's (1943) and Hans Asperger's (1944, cited in Frith, 1991) insightful observations, supports that individuals with autism learn in a '*spontaneous and - sometimes- exceptional*' way and also show a resistance to learn in conventional ways (Dawson, Mottron, & Gernsbacher, 2008, p. 768). More recently Dawson et al. (2008) have proposed that implicit learning is important in autistic people's cognition although it may not map directly onto neurotypicals' implicit learning. Dawson et al. note (2008) that from very early on implicit learning was believed to play an essential part in savant abilities (e.g., Hermelin & O'Connor, 1986), but only recently has it been formally put forward as a mechanism that could explain the exceptional skills in savant syndrome (Happé & Vital, 2009; Mottron, Dawson, & Soulières, 2009).

The present thesis concentrates on implicit learning of visuospatial context in ASD using the contextual cueing paradigm (Chun & Jiang, 1998). Contextual cueing has been used extensively over the last decade in visual research on TD individuals, generating insights about how people acquire sensitivity to the regularities of objects on a display. Although using a single paradigm may appear limited, it has been necessary for the attainment of a deeper understanding of the topic at hand, especially because it appears that the nature of implicit learning of context in autism is more complicated than initially anticipated. Also, it is of interest to study contextual cueing in ASD because it is a paradigm that is based on the ability to learn a visuospatial context and people with ASD are known for their strengths in visuospatial skills.

## General Introduction

Apart from the contextual cueing task used here, other implicit learning tasks such as sequence learning (Nissen & Bullemer, 1987) and artificial grammar learning (Reber, 1967) have been studied in autism. While, all the different implicit learning tasks measure the ability to detect and encode perceptual regularities, they are importantly different between them, because learning is not supported by the same brain areas (e.g., Howard, Howard, Dennis, Yankovich, & Vaidya, 2004; Negash et al., 2007). Thus, although the different tasks come under the umbrella of implicit learning they are not supported by a common process and so comparing their results with that of the contextual cueing studies employed in the present thesis may not be well justified. However, a reference is given to the different implicit learning studies in autism because it is still valuable to contrast how performance in these different forms of implicit learning manifests in autism.

As an introduction to the studies that are presented in this thesis, the present chapter will provide a general overview of implicit learning in TD individuals and those with ASD with a particular emphasis on the spatial context form of implicit learning. This chapter ends with a description of cognitive theories of autism that make similar predictions about performance in the contextual cueing task. It must also be noted the individuals of the clinical group who took part in the present thesis had a diagnosis of high-functioning autism or Asperger's syndrome and together they will be referred to under the umbrella term 'ASD', whereas the term 'autism' will be used to refer to the disorder in an abstract sense.

### 1.2. What Is Implicit Learning?

#### *1.2.1. Definition*

Whenever we are repeatedly exposed to reoccurring information, even when not intending to learn that information, some implicit learning may result and be retained in memory. Currently, one of the most frequently used descriptions of implicit learning is the acquisition of new information without intention to learn or consciousness of the resulting knowledge (Berry & Dienes, 1993). Learning is considered unintentional as participants are not asked to learn the contingencies that they are presented with and it is also considered unconscious, because participants are unaware of the change in their behaviour. Arthur Reber (1967) was the first to coin the term implicit learning in his seminal study of artificial grammar learning, which remains one of the most widely studied implicit learning tasks. Participants were asked to memorise a series of letter strings that were constructed using a set of rules (grammar). Reber (1967) found that when asked to classify novel strings as conforming to the rules or not, participants performed at a level better than chance, while they found it difficult to report verbally the rules they had learned.

Since Reber's work in the 1960s a plethora of studies on implicit learning has accumulated and there are at least two issues that have become controversial. One of the theoretical issues that researchers face when studying implicit learning is that there are at least a dozen definitions of the term and different paradigms to study it. So, for instance, while in an artificial grammar learning task participants learn combinations of letter stimuli that are presented simultaneously, in another well known implicit learning task, the serial reaction time task (Nissen & Bullemer, 1987), participants learn combinations of spatial locations that occur not simultaneously but over time (for reviews see: Frensch & Runger, 2003; Perruchet, 2008). Frensch and

## General Introduction

Runger (2003) conclude that the learning mechanisms and the mental representations that are acquired are not the same across the tasks and that learning in one task may not be comparable to learning in another task. In other words, the different implicit learning tasks may not be merely variations of a common process and learning in one task may not generalise to learning in another.

An empirical issue in the study of implicit learning relates to how one can measure the intention-free and awareness-free aspect of implicit learning (Frensch & Runger, 2003). Both aspects have been scrutinised and there seems to be more general agreement that learning is unintentional, while the ‘unconscious’ aspect of learning is more controversial. In a review of a number of implicit learning tasks, Shanks (2005) has disputed their ‘unintentional’ aspect, on the basis of evidence that often implicit learning can only occur under conditions in which the information is attended. Shanks (2005) argues that if information needs to be attended in order to be learned then it cannot be considered as purely automatic and unintentional. Also, in their seminal article, Shanks and St. John (1994) question the ‘unconscious’ aspect of implicit learning on the basis of problems relating to the validity of the tests that have been used to measure awareness. Therefore, what is a suitable test of awareness and whether it is sensitive enough to detect conscious information has been a matter of controversy (for reviews see: Perruchet, 2008; Shanks, 2005). For instance, according to Shanks (2005, p. 207), subjective measures that rely on one’s inability to verbalize rules are not adequate measures of awareness because they are not sensitive to all of the conscious knowledge and do not “*measure the same stored knowledge that is actually controlling behaviour*”. Instead, the author proposes that objective measures such as recognition tests are probably the best measures of awareness.

### 1.2.2. *Functional Dissociations*

A few studies have attempted to dissociate the contributions of implicit learning from implicit memory, but the greatest interest and controversy has been focused on trying to find out how implicit learning is different from explicit learning. In terms of the former distinction, implicit learning has been studied as a process distinct from implicit memory since the 1990s (Buchner & Wippich, 1998). Although, the distinction between learning and memory is not straightforward, mostly because they are two processes that cannot be easily studied in isolation from one another (Shanks & St. John, 1994), some attempts have been made to measure their contributions separately.

Firstly, *implicit learning*, which refers to how knowledge is acquired, i.e., without awareness and incidentally, is measured by faster and/or more accurate performance in the previously seen compared to the newly presented stimuli (Cleeremans & Dienes, 2008; Reber, 1989). Secondly, *implicit memory*, which is used to refer to how knowledge is stored, is usually assessed using a recognition test at the end of a learning phase (Schankin, Stursberg, & Schubö, 2008). If participants cannot recognise the displays that they have previously seen at a rate better than chance, then this is taken as evidence of implicit memory. Thus, implicit memory refers to the influence of prior experiences on one's behavior in absence of recollection of these past experiences (Dienes & Seth, 2010; Howard, 2001) while implicit learning refers to the unaware and/or unintentional manner of knowledge acquisition.

The second distinction which has been a topic of great interest in cognitive psychology is that between implicit learning and explicit learning. In a detailed account, Dienes and Berry (1997) summarized that the two processes can be distinguished on the basis of the following features: Firstly, implicit learning in

## General Introduction

contrast to explicit learning exhibits limited transfer of the acquired knowledge to related tasks. Secondly, implicit learning tends to be incidental rather than an intentional process that is associated with the encoding of specific rules. Thirdly, implicit learning shows greater robustness over time.

This distinction between implicit and explicit learning has also been a controversial topic within neuroscience, particularly in relation to whether there are also distinct implicit and explicit memory systems. On the one hand, some theorists support what is known as the multiple-systems account (e.g., Gabrieli, 1998; Squire, 2004). According to this account, one memory system is the declarative, supported by the hippocampus and medial temporal lobe structures and the other is the procedural or nondeclarative memory system, supported by cortical and subcortical structures (Poldrack & Foerde, 2008). The earliest and most compelling evidence in support of the multiple systems view derived from studies on amnesic patients, which showed intact performance on tests of nondeclarative memory and impaired performance on tests of declarative memory (for a review, see Poldrack & Foerde, 2008).

However, others have challenged the multiple-systems view by proposing that a single memory system exists (e.g., Kinder & Shanks, 2003; Nosofsky & Zaki, 1998). According to the single-system view, explicit and implicit learning constitute different manifestations of the same underlying system (Shanks, 2005). In support of the single-system account lies evidence of computational models that can produce the aforementioned dissociations between declarative and non-declarative measures using a single connectionist model of learning that does not require functionally or neurally distinct memory systems (Berry, Shanks, & Henson, 2008; Kinder & Shanks, 2003). However, the single-system account has been criticised as lacking parsimony because although it explains the data through a single mechanism, it fails to explain many of

the neuroscientific data that the multiple-systems account can successfully explain and also because multiple free parameters are added in the connectionist models without their neural plausibility being taken into account (Poldrack & Foerde, 2008). To date, evidence that support the hypothesis of implicit and explicit processes as distinct systems appears to be more convincing and in the present thesis recognition tasks will be administered in an attempt to reveal which of the two dominate performance.

### 1.3. Implicit Learning of Spatial Context in Typical Development

The contextual cueing paradigm is based on the idea that in familiar contexts observers are able to extract information more quickly than in unfamiliar contexts. This is typically shown in a visual search task in which occasional displays are exactly repeated during the course of a set of trials. As first shown by Chun and Jiang (1998), detection of the target is found to be faster in the repeated displays than in those that do not repeat. The authors argued that repeated configurations provide a ‘contextual cue’ that guides visual attention towards the target location. The implicit nature of contextual cueing is revealed by the finding that observers are typically unaware of the repetition and are unable to recognize the repeated displays during a recognition test.

#### *1.3.1. Contextual Cueing as an Index of Local Processing*

While in their original study, Chun and Jiang (1998) showed contextual cueing effects by repeating the entire screen (global configuration), more recent research by Olson and Chun (2002) has shown that contextual cueing can occur even if only half of the screen is repeated/invariant while the remaining half is novel/random. More specifically, Olson and Chun (2002) compared a condition in which the local part of the target (short-range context) was repeated, against a condition in which the non-



## General Introduction

local part on the opposite side of the screen was repeated (long-range context), while in both conditions the remaining parts of the configuration changed randomly across the blocks (see Figure 1.1). Olson and Chun (2002) showed that contextual cueing occurs in the local condition but not in the non-local condition and interpreted these findings as showing that observers are more sensitive to learning the local configuration neighboring the target, rather than the non-local configuration which is located further away from the target.

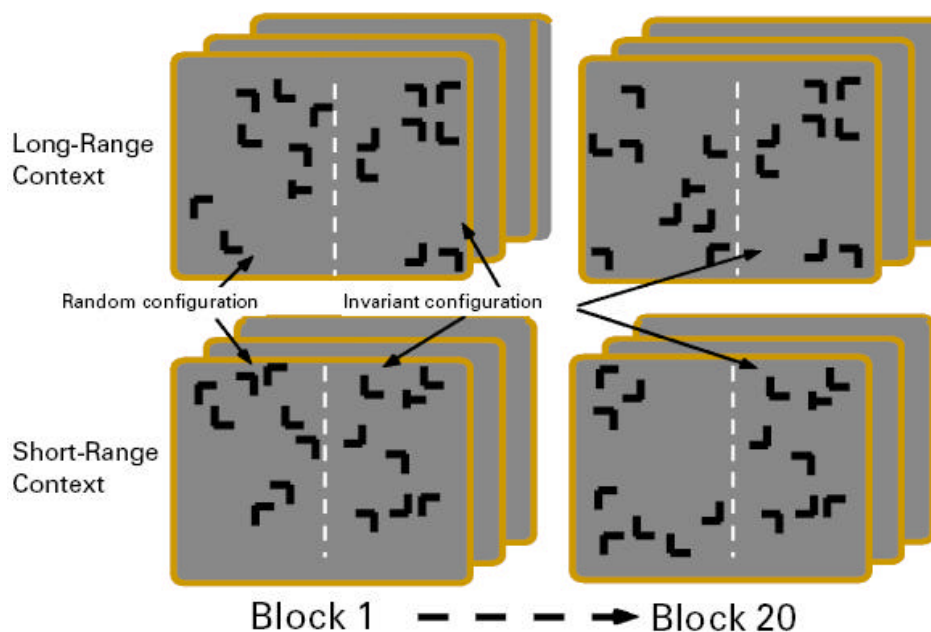


Figure 1.1. Reproduction from Olson and Chun (2002) ©.

In a second experiment the authors argued that non-local learning can actually occur, but only when there is no intervening material between the target and the repeated context. In particular, findings showed that although there was no learning of the non-local configuration when there were intervening material between the target and the repeated configuration (Noise Long-Range Context), observers were able to

## General Introduction

learn the non-local context in a condition in which there was no intervening noise between the target and the repeated context (Space Long-Range Context) (see Figure 1.2). This latter condition was named Space Long-Range condition, because it was created by repeating half of the display with the target always placed in the opposite random half, while between the two halves there was a row of no items. To sum up, the ability to associate a target with its repeated context is not constrained by spatial distance, since observers can learn both the local and the non-local context, but they tend to encode only the local context when the whole context is repeated.

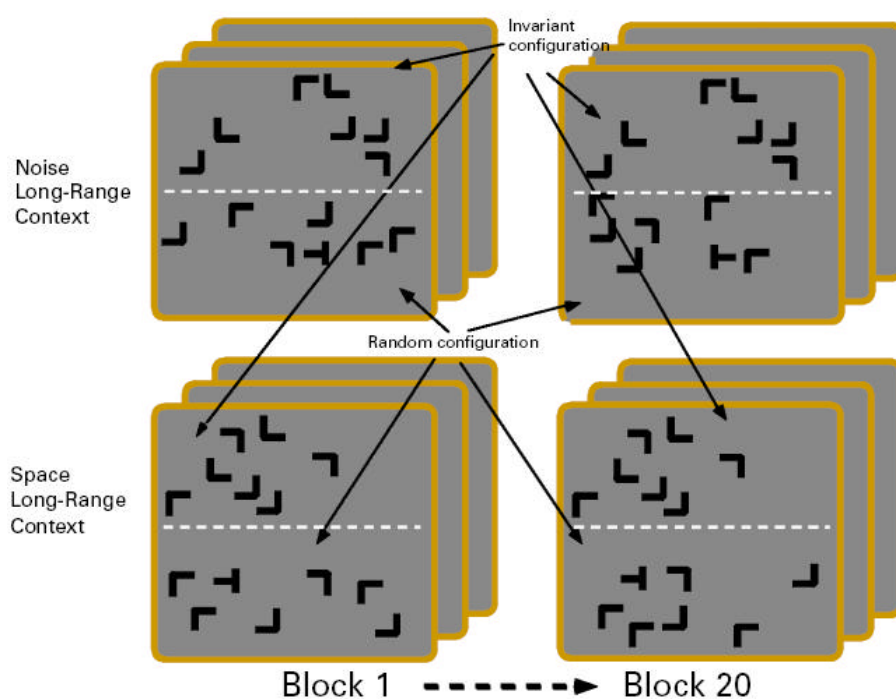


Figure 1.2. Reproduction from Olson and Chun (2002) ©.

Further experiments by Brady and Chun (2007) revealed that learning is even more locally constrained than reported in Olson and Chun, since contextual cueing could occur by repeating only the two items in the vicinity of the target. In addition,

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the authors showed that the repetition of these two local items could produce learning equivalent to when the entire screen is repeating, which indicated that observers preferentially encoded the very local context of the target rather than the global configuration. Brady and Chun (2007) also replicated that non-local learning occurs when there is no intervening noise which shows how contextual encoding can extend further when local information is not repeated. The authors concluded that although spatially local learning drives most of the contextual cueing effect, the stimuli and task characteristics determine the spatial extent of encoding. In other words, observers encode the local context when this is repeated, but they can also encode the non-local context when the local is not repeated. Thus, it seems that contextual cueing is more of a local processing, rather than a global processing task.

### *1.3.2. The Attentional Guidance View*

It is suggested that the mechanism that drives learning in the contextual cueing task is an attentional guidance mechanism, according to which, memory of the repeated spatial context serves as a cue that guides attention towards the target location and this helps to speed the search process in the repeated trials leading to faster target detection. One of the predictions arising from the attentional guidance view is that because search is memory-based it must be faster than the serial perception-based search, and this will be especially the case in displays of larger number of items in which a serial attention scan is operative (Jiang, Makovski, & Shim, 2009).

However, the view of an attentional guidance mechanism that drives learning has recently been challenged. Kunar, Flusberg, Horowitz and Wolfe (2007) demonstrated that contextual cueing effects did not increase with larger set sizes, as the attentional guidance view would predict and also that there was no contextual cueing when the target and the distractors activated competing responses. Kunar and

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colleagues (2007) proposed that other factors such as response selection may contribute to contextual cueing effects. According to their *response selection* hypothesis, contextual cueing can be partly explained by search times being faster not as a result of the search process becoming more efficient, but because once a target in a repeated display is identified, observers will respond faster to it, possibly because in familiar displays there is no need to double check that the target was found. In other words, the response selection hypothesis, argues that search time is facilitated at the response stage, and not during the search process.

However, the main argument against the attentional guidance view of learning not increasing with larger number of items on the display is not entirely convincing. Jiang and colleagues (2009) cite evidence that shows how contextual cueing is actually smaller in higher set sizes possibly because the displays become less distinctive (Hodsoll & Humphreys, 2005) and evidence that shows learning to be constrained around the few items near the target rather than on all the items of a display (Brady & Chun, 2007; Olson & Chun, 2002). Also, Makovski and Jiang (in press) argue that in order for memory to guide attention, recognition needs to take place first, but this does not occur in every trial (Peterson & Kramer, 2001) and in particular in trials with greater set sizes which are more difficult to recognize. Finally, Jiang and colleagues (2009) point to eye-tracking studies in real world-scenes (Brockmole & Henderson, 2006a) which have demonstrated that once learning is acquired, fewer eye movements are needed to locate the target in the repeated displays, thus suggesting that the search process is efficient and it is not the response stage which drives learning. Therefore, it appears that the attentional guidance view, despite its criticisms, remains the dominant view of how contextual cueing is driven.

### *1.3.3. Developmental Effects*

Contextual cueing in typical development has been found to be sensitive to developmental differences and optimal in adolescence and adulthood. Vaidya and colleagues (2007) investigated implicit learning of spatial context using the contextual cueing paradigm in two different age groups: school children (aged 6-13) and university students (aged 18-22). Findings revealed that school-age children did not obtain reliable contextual learning whereas older participants did, which led them to the conclusion that implicit learning of spatial context is still immature in late childhood, but is well developed in early adulthood. The authors explained that the lack of contextual learning in late childhood is likely to arise from incomplete maturation of the relevant brain regions, i.e., the medial temporal lobes, which are known to mediate context learning.

## 1.4. Influences on Implicit Spatial Context Learning

### *1.4.1. Visual Search and Selective Attention*

Visual search is a paradigm that has been widely used to assess the operations involved in selective attention (Nobre, Coull, Walsh, & Frith, 2003). In a typical lab-based visual search task, observers search for a target item amidst a number of distractor items on a computer display and the efficiency of their performance is based on reaction time measures. Everyday examples of visual search include search for a word in a dictionary or search for ones' keys in a room. But as “*the eyes provide the central nervous system with more information than it can process*” (Wolfe, Butcher, Lee, & Hyle, 2003, p. 483), the brain has been equipped with efficient mechanisms that focus attention to a limited set of stimuli and/or ignore other, resulting in the prioritization of the behaviourally relevant aspects of the visually rich environment (Chun & Wolfe, 2001).

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The control of attention in visual search tasks has been categorized into top-down and bottom-up: top-down attention, which is also known as endogenous (Posner, 1980) or goal driven (Yantis, 1998), is driven by ones' previous knowledge and experience, whereas bottom-up attention, also known as exogenous (Posner, 1980) or stimulus-driven, is driven automatically by salient features of the stimulus (Chun & Wolfe, 2001; Wolfe, 1998). Instances of bottom-up guidance include features such as colour and orientation (e.g., Treisman & Gelade, 1980) and abrupt onsets (Yantis & Jonides, 1984). Wolfe, Butcher, Lee and Hyle (2003) assert that top-down guidance can be either explicit, when observers are given verbal instructions about where on the display to look for the target, or implicit when observers' performance is facilitated by their previous encounters of the target (Chun & Jiang, 1998; Geng & Behrmann, 2005; Walthew & Gilchrist, 2006). For instance, Chun (2000) claimed that the contextual cueing effect (Chun & Jiang, 1998) constitutes a form of implicit top-down guidance of attention because it refers to more efficient detection of targets when they appear in previously viewed spatial configurations of distractors. In other words, memory of the spatial context of repeated distractors serves as a cue to guide attention towards the target location.

In simple visual search tasks that employ low-level stimuli it is easier to distinguish between bottom-up and top-down influences of attention, but when scene stimuli are used, can there also be a prediction on where attention will be guided? Is it top-down, bottom-up or both factors that will influence the decision of where to attend? Computational models have been instrumental in addressing these questions. For instance, Navalpakkam and Itti (2005) propose that there are four important and interacting factors that can account for where people will look at, when they are presented with a scene: 1.) bottom-up factors, such as the saliency of a target that

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captures automatically one's attention, 2.) the gist and layout of the scene, which guide attention in a top-down manner, 3.) prior knowledge of the target which renders the target a salient stimulus, and 4.) the task itself, which guides attention to task relevant areas. The authors were able to model how these factors influence the guidance of attention and even achieved to reproduce the basic human visual search behaviour. Similarly, a computational study on the contextual guidance of attention (Oliva, Torralba, Castelhana, & Henderson, 2003) signifies the contributions of both saliency and top-down knowledge of context on performance. Oliva and colleagues (2003) compared scan patterns of human eye-movements and patterns derived by a pure saliency model and a model that integrated context information with image saliency. Findings revealed that the model which resembled more closely the human patterns of eye-movements was the one that integrated salient and contextual information. Therefore, computational models have confirmed and extended the evidence that human attention is guided not only by bottom-up factors, but also from top-down influences of contextual information in particular.

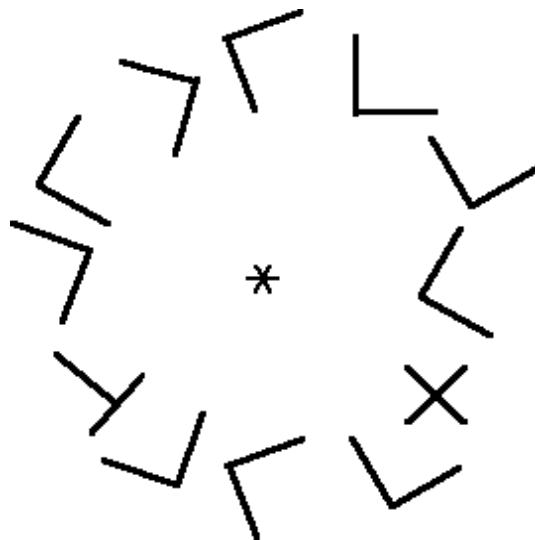
### *1.4.2. Eye -movements and Attentional Deployment*

Eye movements provide a direct method to study the allocation of attention, because when the eyes move so does the focus of attention (Shepherd, Findlay, & Hockey, 1986). When a person looks at an object the image of this object is directed to the fovea, which is the part of the retina that is responsible for detailed visual processing (Boraston & Blakemore, 2007). The images in the fovea are constantly changing as a result of moving our eyes very rapidly (saccades) several times each second, but between saccades the image stays relatively stable and this indicates that an object is fixated (Henderson, Brockmole, Castelhana, & Mack, 2007). The location of fixations

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that occur between saccades constitute the behavioural index of the locus of attention (Shepherd et al., 1986).

However, as Shepherd et al. (1986) point out, attention can be deployed in parts of the visual field without moving the eyes. An example of this covert shift of attention can be shown in the following illustration. If one's eyes are fixated in the asterisk presented at the centre, one can still see the periphery of small letters without needing to move the eyes (Wolfe, 1998).



*Figure 1.3.* Reproduction from Wolfe (1998) ©.

Findlay (2009) describes how influential were initial accounts of attention in visual search tasks which portrayed attention as being a passive process of scanning that was deployed faster than eyes could move, thus implying – but not explicitly stating- that attention in visual search was covert (Treisman & Gelade, 1980). This notion of a passive covert attention rendered eye movements as incidental in attentional deployment, although eye movements were ubiquitous in visual search



(Findlay & Gilchrist, 2005). A new perspective in the understanding of how visual attention works, termed *active vision* (Findlay, 2005; Findlay & Gilchrist, 2001; Findlay & Gilchrist, 2003) contends that covert visual attention is a process that assists overt visual attention (saccadic eye movements) by processing the stimulus on the location that the next eye movement will fall to, thus allowing a faster processing of that material when fixated. Consequently, covert attention is closely linked to eye movements and the active vision perspective draws emphasis on eye movements being the foundation of an active vision process during which the eyes are directed to task-relevant stimuli of the environment (Castelhano, Mack, & Henderson, 2009; Findlay, 2009).

### *1.4.3. The Definitions of Context*

The visual system exploits contextual associations present in both lab-based visual search tasks as well as in the real-world in order to reduce complexity and facilitate object recognition (Oliva & Torralba, 2007). In visual cognitive science, two approaches have been used to conceptualize context: the object-centered and the scene-centered approach (Greene & Oliva, 2009; Torralba, Oliva, Castelhano, & Henderson, 2006). The object-centered account of context has been inspired by the observation that objects are almost always accompanied by other objects (Oliva & Torralba, 2007) and therefore, one way to define the context of an object is in terms of the relationship with other objects that are co-occurring in the same scene and can facilitate object and scene categorization (Torralba et al., 2006). To build up this type of context representation, the recognition of one diagnostic object (e.g., computer) can activate knowledge about the possible presence and location of other objects (e.g., desk) (Torralba et al., 2006). As Torralba and colleagues (2006) note, in the contextual cueing studies of abstract stimuli a more local-based approach seems more

likely to be used, since observers encode the spatial associations of locally grouped objects.

On the other hand, in the scene-centered approach, context is represented in a more gestalt way, by using the information from global statistical properties of a scene, such as scene layout and structure, without the need to recognize the local objects (Torralba et al., 2006). For instance, when an image has been degraded and appears blurred so that the individual objects are not recognizable, the semantic category of a scene can be extracted in order to facilitate object recognition (Schyns & Oliva, 1994). Thus, the information from the context as a whole can facilitate object recognition and this approach is most likely used in contextual cueing studies in which real-world scenes are used (Torralba et al., 2006). To conclude, context can be perceived and defined, either as a combination of co-occurring objects or as a holistic global property and these two approaches of representation may often complement each other (Greene & Oliva, 2009).

### 1.5. Autism Spectrum Disorders

The concept ‘autism’ was introduced almost 70 years ago when Kanner (1943) described the unique condition of 11 children (8 boys, 3 girls) as ‘*autistic disturbances of affective contact*’ and, nearly simultaneously with Leo Kanner, when Hans Asperger (1944) published his work on ‘*autistic psychopathy*’. Autism, is derived from the Greek word *autos* (αὐτός, meaning *self*), and is intended to reflect a lack of interest in another self and a primary focus on own self’s interests and goals (Baron-Cohen, 2005). Very early on, many fascinating peculiarities in the behaviour of children with this condition were documented and not least their islands of exceptional ability in domains such as rote memory (e.g., Kanner, 1943). Between then and now much research has taken place in order to generate the behavioural

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criteria that are required for a diagnosis of autism and in order to establish the extent to which autism has a genetic basis.

Lorna Wing (1988) recognised that autism is part of a spectrum of disorders and together with Judith Gould (Wing & Gould, 1979) established the behavioral criteria for a diagnosis in autism (see Happé, 1994a for a historical review). The criteria required for the diagnosis of autistic disorder are deficits in three symptom domains: 1.) Qualitative impairments in social interaction, such as lack of personal relationships; 2.) Qualitative impairments in communication, such as language delay and lack of eye-to-eye gaze; 3.) Restricted repertoire of activities and interests, such as stereotyped body movements and preoccupation with parts of objects (American Psychiatric Association, 2000; Wing & Gould, 1979). A diagnosis of autism is characterized as low-, medium- or high-functioning autism based on the individuals' IQ level (Baron-Cohen, 2006). Asperger's syndrome has similar symptoms to autism, but no language delay and normal or above average IQ. However, there is no universal consensus about the syndrome boundaries (Volkmar, State, & Klin, 2009) as well as how objective or helpful they are in clinical practice (Leekam, 2007; Wing, 1997). Regardless of the specific diagnosis, autism manifests in different ways depending on the individual's level of ability as well as the co-morbidity with other conditions (Wing, 1997, 2007).

Finally, the concept 'disorder' is used to characterize the severity of symptoms and their major impact on one's everyday life, although in recent years the term has started to be substituted with the milder term 'condition' (e.g., Baron-Cohen, Ashwin, Ashwin, Tavassoli, & Chakrabarti, 2009; Happé & Frith, 2009; Plaisted-Grant & Davis, 2009).

### 1.6. Hypotheses of Implicit Learning Impairments in Autism

In the last decade, two hypotheses have been proposed; firstly, that individuals with ASD have a fundamental difficulty with implicit learning and secondly, that this could underlie the development of the social, communicative and motor impairments present in autism. Initially, the proponents of the '*motor skills deficits*' hypothesis (Mostofsky et al., 2000) provided evidence for this problem. Mostofsky et al. (2000) examined 11 individuals with autism (age range 6.8–17.8 years) and 17 age- and IQ-matched controls in the serial reaction time task (Nissen & Bullemer, 1987). This task involved making a manual response as fast and accurately as possible to a stimulus that appeared at one of several locations on a computer display. Unknown to the participants, the sequence of successive stimuli followed a repeating pattern. Faster reaction time to the repeated sequence compared to a random sequence was taken as an index of implicit learning. Findings indicated impairments in the implicit sequence learning in the autism group and the authors hypothesised that these impairments may contribute to the core deficits in autism in those areas that are known to develop implicitly, such as social interaction, communication and motor activities.

However, four recent studies have not found impaired learning in Nissen and Bullemer's (1987) serial reaction time task. These recent studies have attributed the discrepancy between their findings and those of the above study on methodological issues such as the use of very lengthy sequences which may have been very difficult to learn in the Mostofsky et al. study (D'Cruz et al., 2009; Gordon & Stark, 2007), or the design of the task used by Mostofsky et al. that did not adequately assess implicit learning but rather encouraged the use of explicit strategies (Brown, Aczél, Jiménez, Kaufman, & Plaisted-Grant, in revision). Finally, Barnes and colleagues (2008) suggest that the slower responses of the autism group in the Mostofsky et al. study

indicated that motor rather than mnemonic impairments may have led to the reduced expression of learning in the autism group.

Although the '*motor skills deficits*' hypothesis is not strongly supported using the serial reaction time task, some further studies by Mostofsky and colleagues suggest that implicit learning in people with autism may be atypical when there is a motor component involved. For instance, in a recent study of motor sequence learning, Mostofsky and colleagues have argued that people with autism may show greater reliance on explicit learning which either interferes with implicit learning or is used to compensate for their implicit learning impairments (Gidley-Larson & Mostofsky, 2008). Also, neuroimaging findings of decreased connectivity across the motor execution network in children with autism relative to controls have led Mostofsky and colleagues (2009) to propose that disruption in the neural systems responsible for the acquisition of motor skills, may also contribute to the social and communicative impairments found in autism.

An alternative hypothesis known as '*learning compensation*' was also put forward to explain implicit learning impairments in autism and proposed that these are fundamental to the development of the disorder (Klinger & Dawson, 2001; Klinger, Klinger, & Pohlig, 2007). According to this hypothesis, people with autism have implicit learning impairments and they compensate for them by using explicit learning strategies. Klinger and colleagues (2007) proposed this hypothesis based on preliminary evidence from tasks of category learning and artificial grammar learning. In a set of studies using the artificial grammar learning task, Klinger and colleagues (2007) found that in accordance to the '*learning compensation*' hypothesis children with ASD showed significantly less implicit learning than the control group and also that implicit learning in ASD was correlated with tasks measuring explicit learning

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processes. Recently, Brown and colleagues (in revision) argued that the adapted version of the artificial grammar learning task which was employed by Klinger and colleagues (2007) may have encouraged explicit learning, and that when Brown et al. employed the original version of the task, they found normal implicit learning in children with ASD.

In a study of category learning, Klinger and Dawson (2001) examined whether individuals with low-functioning autism were able to perform a categorization task using an implicit or an explicit rule. Klinger and Dawson (2001) showed that exposure to information across repeated trials did not enhance implicit learning of a new category in individuals with low-functioning autism as it did for control individuals, but when provided with an explicit rule of categorizing, individuals with low-functioning autism were successful in learning a new category. This result, as the one above, indicated that people with autism may rely on explicit processes of learning more than implicit ones. However, impairments in category learning have not been replicated by more recent studies which examined individuals with high-functioning instead of low-functioning autism, and which used a recognition test to assess categorization performance, instead of an ambiguous question that was used in the above study (Molesworth, Bowler, & Hampton, 2005; Soulières, Mottron, Giguère, & Larochelle, submitted; Soulières, Mottron, Saumier, & Larochelle, 2007).

Both the '*learning compensation*' and the '*motor skills deficits*' hypotheses, outlined above share an emphasis on the association of implicit learning deficits with the development of the core symptoms in autism. To examine this association, Klinger and colleagues (2007) created a composite measure of implicit learning, by combining performance on the category learning and the artificial grammar learning tasks, as well as a composite measure of each of the three diagnostic areas, i.e., social

and communication symptoms as well as repetitive behaviors, measured using a number of questionnaires such as the Children's Social Behavior Questionnaire (Luteijn, Luteijn, Jackson, Volkmar, & Minderaa, 2000). Klinger and colleagues (2007) reported significant negative correlations of implicit learning in ASD with social and communication symptoms (both  $r_s > -0.5$ ,  $p < 0.001$ ) as well as repetitive behaviors ( $r = -0.25$ ,  $p < 0.01$ ) confirming the hypothesis that implicit learning is associated with the behavioral symptoms in ASD. However, a similar, although weaker pattern was also found in the TD group (social:  $r = -0.1$ ,  $p < 0.20$ , communication:  $r = -0.29$ , repetitive behavior:  $r = -0.33$ , both  $p_s < 0.05$ ), and since the authors did not assess whether the difference in strength of the correlations between the two groups was significant, it is not clear whether the associations are specific to the ASD group or whether they characterize both groups of participants. On the other hand the proponents of the '*motor skills deficits*' hypothesis, have not yet empirically examined whether implicit learning and behavioral symptoms are associated, but recent evidence indicate that they are not. For instance, Brown and colleagues (in revision) found that the correlation between performance in the Social Communication Questionnaire (Rutter, Bailey, Lord, & Berument, 2003), a screening tool of autistic symptoms, and performance in four different implicit learning tasks was not significant (range of Pearson's  $r = -.26$  to  $-.16$ ,  $p_s = .14$  and  $r^2 = -.07$ ). Thus, although the hypothesis of implicit learning being linked to the core symptoms in autism is a logical one, to date evidence does not strongly support it.

### 1.7. Implicit Learning of Spatial Context in Children with ASD

Recently, the contextual cueing task (Chun & Jiang, 1998) was studied in children with high-functioning autism/Asperger's syndrome and findings revealed that implicit learning of spatial context is preserved in this condition. For instance, Barnes and

colleagues (2008) examined 14 children with ASD (aged 8 to 14 years) and 14 control children (aged 7 to 14 years). Using Chun and Jiang's (1998) original design, Barnes and colleagues (2008) presented participants with configurations comprised of a stimulus array of distractors (letter shape Ls) within which a target was embedded (letter shape T). Half of these configurations were repeated across blocks whereas the other half was novel. Results showed that children with ASD, like TD comparison children, responded faster to repeated configurations compared to novel configurations. Similarly, Brown and colleagues (in revision) who examined a similar cohort of 26 children with ASD (aged 9 to 14 years) using an adapted version of Chun and Jiang's (1998) contextual cueing, failed to find impairments in autistic children's implicit learning of spatial context as well as on a number of other implicit learning tasks.

### 1.8. Theoretical Predictions

There is a considerable interest in identifying the cognitive mechanisms that may underlie autism. Such an understanding could contribute to the identification of what causes the condition as well as to the development of effective interventions. Theories have been developed on the idea that a single cognitive explanation could account for the three core features in autism. However, recent research suggests that the assumption of a single explanation for autism should be abandoned, because the triad of impairments appears to be independent at the cognitive, genetic and neural level (Happé, Ronald, & Plomin, 2006; Pellicano, Maybery, Durkin, & Maley, 2006) pointing to the need for separate explanations of the core features in autism. However, cognitive theories are valuable in explaining specific aspects of autism and those that are reviewed and considered throughout this thesis are those that attempt to explain



the assets and deficits of attentional and perceptual abilities in autism<sup>1</sup> (for theoretical reviews see Dakin & Frith, 2005; Simmons et al., 2009).

### *1.8.1. Weak Central Coherence*

Weak central coherence theory in its original formulation (Frith, 1989; Frith & Happé, 1994), proposed that individuals with autism excel in tasks where attention to local information is advantageous, but do poorly in tasks that require integration of features in order to derive the configuration and meaning of a stimulus. More recently, Happé (1999) proposed that autism is characterized by a detailed-focused cognitive style that allows for better processing of features and details over processing of context and configurations rather than by a typical bias for global processing. In more recent years, the theory has been reformulated even more substantially, to propose that local and global processing may be dissociable and while accumulating evidence strongly support the detail-focused cognitive style rather than an impaired global-level processing, the evidence for the latter is still conflicting (Happé & Booth, 2008; Happé & Frith, 2006; Happé & Vital, 2009).

One of the earliest and most replicated evidence of a local processing superiority in autism came from the Embedded Figures Test (Witkin, Oltman, Raskin, & Karp, 1971) in which people with ASD show faster detection of parts embedded in larger fields (e.g., Jarrold, Gilchrist, & Bender, 2005; Jolliffe & Baron-Cohen, 1997; Shah & Frith, 1983). Another visual task of weak coherence is the Wechsler Block Design subtest (Wechsler, 1981, 1994) in which people with autism, are shown to be faster than control participants in assembling a set of blocks to reproduce a whole

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<sup>1</sup> One of the theories that attempts to explain the cognitive profile of people with ASD, is the ‘Extreme Male Brain’ theory (Baron-Cohen, 2002). This theory is not included here, mainly because the implications it has for visual processing in autism are not direct (Simmons et al., 2009).

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design (e.g., Caron, Mottron, Berthiaume, & Dawson, 2006; Happé, 1994b; Shah & Frith, 1983, 1993). For instance, Caron et al. (2006) report that in a sample of 92 people with autism and 112 without autism, perceptual peaks in the Block Design test were more frequent in the autistic population (47%) than the non-autistic population (2%). Also, free-choice tasks such as those using Navon-type stimuli (Navon, 1977), that consist of a large letter (global structure) composed of small letters (local structure), have revealed that individuals with autism are faster to identify the local letters and/or they also show greater interference from local to global stimuli (e.g., Behrmann et al., 2006; Plaisted, Swettenham, & Rees, 1999; Rinehart, Bradshaw, Moss, Brereton, & Tonge, 2000) compared to TD individuals who show the opposite pattern of results, i.e., faster identification of global letters and global-to-local interference.

The weak central coherence theory's original claim of a core deficit in central (perceptual and conceptual) coherence remains conflicting (see López, 2007; for a recent review). This claim was supported by early evidence of impairments in context processing of verbal material (Frith & Snowling, 1983; Hermelin & O'Connor, 1967), but to date evidence show that impairments can disappear under conditions in which attention is directed to the contextual significance of the stimuli (e.g., Happé, 1997; Jolliffe & Baron-Cohen, 1999; López & Leekam, 2003). Similarly, in the visual domain, it has been shown that global processing is possible in autism when participants are cued or instructed to use global information (e.g., López, Donnelly, Hadwin, & Leekam, 2004; Plaisted et al., 1999). For instance, López et al. (2004) showed that the ability of adolescents with ASD to derive the holistic representation of faces was dependent on the presence of a cue; in non-cued conditions ASD participants did not deploy holistic processing.. These results indicated that processing

of wholes may not be the default way of processing a stimulus, but this could not suggest that such processing is impaired in autism. However, in a recent article, Happé and Booth (2008) supported that people with ASD do show integration difficulties when they are tested in tasks in which local processing is not helpful. Thus, it remains unresolved whether local processing arises from impairments in integrating information into a coherent whole.

So far, the aforementioned studies that entailed visual stimuli required a *Gestaltist* processing, but there is another aspect of context processing which relates to the influence from prior real-world knowledge and expectations (Loth, Gómez, & Happé, 2008). Frith (2003) proposed that this kind of top-down attentional modulation is diminished in autism and can lead to impairments in some social skills such as face perception (Bird, Catmur, Silani, Frith, & Frith, 2006). To investigate this proposal, Loth and colleagues (2008) employed a ‘change blindness’ paradigm (Rensink, O’Regan, & Clark, 1997), which typically shows that observers fail to detect even large changes to previously viewed scenes, such as object substitutions, but tend to detect faster those changes that are scene-inconsistent rather than those that are scene-consistent, because the former changes are more salient as they do not concur with one’s expectations. Loth and colleagues (2008) showed that individuals with ASD were less accurate and slower than a comparison group to detect the change that related to a substitution of a previously seen object with a scene-unrelated object. This finding confirmed their hypothesis that prior knowledge has less influence on how people with autism detect changes in their environment pointing to reduced top-down modulation in scene perception.

However, there seem to be two constraints to the reduced top-down modulation hypothesis. Firstly, as the authors themselves note, this group difference is

true only when incorrect responses are included in the analysis, whereas when only correct responses are included, then consistent with previous research (Fletcher-Watson, Leekam, Turner, & Moxon, 2006) there are no significant group differences. Also, reduced top-down modulation does not generalize to conditions in which individuals with ASD are attentionally cued, since when asked to identify the *presence* of a cued object in a simple priming task, like individuals in a control group, they are faster to identify an object in contextually relevant scenes rather than in neutral or irrelevant contextual scenes (López & Leekam, 2003).

To recapitulate, the recently reformulated weak (central) coherence theory (Happé & Booth, 2008; Happé & Frith, 2006) suggests that weak coherence is a cognitive style towards local processing rather than a deficit in global processing, since at least under some conditions, such as when explicit instructions are given, people with autism are able to process context and meaning. In addition, the authors postulate that people with autism are able to process information configurally, that is in an item-to-item (chaining) manner, without the need to be cued or instructed, in those tasks that require local rather than global coherence. Happé and Frith (2006) claim that an example of local coherence can be seen in picture sequencing tests such as the Wechsler Picture Arrangement subtest in which people with autism are able to create a coherent story, because this ability rests on connecting neighboring items (chaining) without going beyond the adjacent picture/episode.

### *1.8.2. Enhanced Perceptual Functioning*

The other account that has provided an explanation of the deficits and special abilities in autism is known as the ‘enhanced perceptual functioning’ model (Mottron, Dawson, Soulières, Hubert, & Burack, 2006) which supports that over-development of low-level perceptual operations leads to enhanced performance in low-level tasks,

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without assuming that there is a deficit in global processing. The enhanced perceptual functioning model, like the weak central coherence hypothesis, supports that perception in autism is more *locally oriented* than that of TD people, but in contrast to the weak central coherence, it claims that local processing is mandatory in autism, rather than optional as the term ‘cognitive style’ implies (Happé & Frith, 2006). This is typically shown by the local advantage and local-to-global interference that autistic people show in Navon-type tasks and which Mottron and colleagues support to be a robust finding despite the many methodological differences across the different studies (for reviews see Mottron et al., 2006; Wang, Mottron, Berthiaume, & Dawson, 2007).

However, the enhanced perceptual functioning model does not assume the presence of a global processing deficit, but supports that global processing is optional in autism and mandatory in non-autistic people. The evidence that there is no global deficit stems from evidence of typical global advantage in Navon-type tasks (Wang et al., 2007) and typical performance in the construction of global representations (Caron et al., 2006; Mottron, Burack, Iarocci, Belleville, & Enns, 2003). Evidence for the optional aspect of global processing, derives from more recent studies using Navon-type tasks which have shown that the level of processing of people with autism, depended on the implicit demands of the task rather than being constrained by the same obligation that non-autistic people have for global processing (Iarocci, Burack, Shore, Mottron, & Enns, 2006; Mottron, Dawson, Bertone, & Wang, 2007) as well as from visual construction tasks, in which autistic people used a local or a global strategy depending on which representation optimized performance or which one was mandatory (Caron et al., 2006).

Another principle of the enhanced perceptual processing model is the existence of a greater autonomy/diminished interaction between low-and high-level processes that may or may not lead to enhanced low-level performance (Mottron et al., 2006; Soulières et al., 2007). This proposal contrasts with the weak central coherence theory's proposal of a deficit in higher level processing which results in superior low-level processing (Frith, 2003). For instance, Soulières (2007) showed that in a task of perceptual categorization people with ASD were less influenced by 'learned expectations', a form of top-down knowledge, in their ability to perform a low-level discrimination task. Similarly, Ropar and Mitchell (2002) showed that the reproduction of the shape of a slanted circle was more accurate in autism which indicated that they were less influenced by prior knowledge.

### *1.8.3. Reduced Generalisation*

An alternative account of the cognitive profile in autism, is the hypothesis of *enhanced discrimination and reduced generalization* (Plaisted-Grant & Davis, 2009; Plaisted, 2000 ; 2001), according to which individuals with autism show reduced perception of similarities and enhanced perception of unique features, which results in poor categorisation and enhanced discrimination. Enhanced discrimination in particular, has been put forward as the mechanism of superior visual search, (Jarrold et al., 2005; O'Riordan, 2004; O'Riordan & Plaisted, 2001; O'Riordan, Plaisted, Driver, & Baron-Cohen, 2001; Plaisted, O'Riordan, & Baron-Cohen, 1998b), because it is thought to facilitate the perception of the unique features of the target thus, rendering it more salient in autistic people's perception. The hypothesis of enhanced discrimination in autism was further examined and replicated in recent eye-tracking studies of visual search tasks (Joseph, Keehn, Connolly, Wolfe, & Horowitz, 2009; Kemner, Van Ewijk, Van Engeland, & Hoge, 2008) as well as in non-visual search

tasks of perceptual and configural learning (Plaisted, Saksida, Alcantara, & Weisblatt, 2003), while reduced generalization was demonstrated more directly in impaired performance on a category learning task that was dependent on the perception of the common features (Plaisted, O'Riordan, & Baron-Cohen, 1998a). However, Mottron and colleagues (2006) propose that the hypothesis of enhanced discrimination is another feature of enhanced perceptual processing rather than an explanatory principle of the cognitive processing in autism.

### *1.8.4. Cognitive Theories on Implicit Learning in ASD*

Related to the issue of superior attentional and perceptual abilities in autism, another issue that is pertinent to this thesis is implicit learning, which has recently been proposed to lie at the heart of superior abilities in autism. It is known that performance on implicit learning tasks can be disrupted when explicit learning is introduced and Happé and Vital (2009) propose that the lack of self-awareness that characterizes people with autism may contribute to the development of those skills that are learned implicitly. This is an original hypothesis that merits investigation since at the moment it is not known whether superior skills in autism are developed implicitly or whether there is a relationship between explicit learning and lack of self-awareness. Mottron and colleagues (2009) have attributed the enhanced performance and the expertise effects found in savants, to an enhanced ability to implicitly detect patterns across stimuli that they have been overexposed to. According to Mottron and colleagues (2009) the implicit nature of savants' skills is manifested in their inability to verbalize what strategies are used, but also in the process of learning itself (which occurs without intention). This hypothesis also merits investigation and seems quite pragmatic given that pattern detection is a key component on all implicit learning tasks.

### 1.9. Aims and Hypotheses

The present thesis aims to explore learning of spatial context in adolescents and adults with ASD and those who are typically developed. Using a visual search task, *contextual cueing* (Chun & Jiang, 1998), we assessed the ability to detect targets faster when embedded in configurations of distractors that occasionally repeated, even though observers were unaware of the repetitions. Visual search is a particularly interesting area because of the superior spatial abilities that have been documented in autism. Also, the contextual cueing literature makes a distinction between local vs. distant processing of context and so it was recognized that this distinction might be particularly relevant to the issue of different perceptual emphases in autism. An additional aim was to examine implicit learning in adolescents/adults rather than children with autism, as it is known that learning of spatial context matures throughout childhood (Vaidya et al., 2007) and therefore it is important to examine learning at an age in which it is matured.

The general hypothesis is that individuals with ASD will show preserved or enhanced perceptual learning of repeating patterns under conditions that involve low-level cognitive operations such as attention to the local elements (Happé & Frith, 2006; Mottron et al., 2006). More specifically, the predictions were as follows: Firstly, we expected to replicate that TD individuals detect targets in repeated trials faster than targets in novel trials. Secondly, the hypothesis of *detail focus/locally oriented attention* predicts that individuals with ASD are particularly good in focusing attention to local parts, regardless of the object's contextual importance. Since on the implicit contextual cueing task, observers anyway tend to attend to and learn the local part of the target rather than the global/whole context, this account would predict that the ASD group will show at least equivalent or even superior learning than the



## General Introduction

comparison group. Thirdly, the hypothesis of *intact local coherence/intact global processing* predicts that individuals with ASD are able to connect and integrate neighbouring items and so according to this account equivalent performance between the two groups in the contextual cueing task is expected, since successful performance in this task, rests on one's ability to connect the neighbouring items of the target. Thus, the predictions arising from weak central coherence and the enhanced perceptual functioning model are similar.

Experiment 1 assessed whether implicit learning of global configurations occurs in ASD. This first experiment formed part of a master's dissertation project which preceded the PhD research, but here a novel analysis and a somewhat different interpretation of the data are presented. Experiments 2 and 3 aimed to explore whether individuals with ASD may have difficulties with the basic process of associative learning that produces the contextual cueing effect, that is the ability to associate a target with its repeated context, rather than with the implicit nature of learning per se. Experiments 4 and 5 aimed to revisit implicit learning of visuospatial context in ASD to explore whether individuals with ASD may show greater learning of local over non-local configurations. A further aim was to improve the design used in the implicit learning study of Experiment 1, for instance by simplifying the surface features of the stimuli through the use of two colors instead of four, and controlling every potentially confounding variable, from the color of the neighboring items to the distribution of the location of targets on the display. In Experiment 6, the aim was two-fold: firstly, to acquire data of online processing with the use of eye-tracking methodology and secondly to assess whether attention to local information may facilitate learning in the ASD group more than the TD group.

## 2. CONTEXTUAL CUEING AND IMPLICIT LEARNING OF VISUOSPATIAL CONTEXT

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### 2.1. Introduction

In the previous chapter the proposal of an implicit learning impairment in autism was reviewed and although the evidence remains conflicting, a general deficit in implicit learning does not seem to characterise autism (Brown et al., in revision). While some explanations of why the evidence is conflicting were presented, more research using the same tasks is needed, in order to elucidate what aspects of implicit learning may be impaired in autism and how these may affect the development of the disorder. A less controversial area of implicit learning in autism is that of spatial context which has been identified as intact in children with ASD. However, there are at least two compelling reasons that performance in this task needs to be studied in older ASD individuals.

Firstly, there is evidence that learning of implicit cues (Maybery, Taylor, & Obrienmalone, 1995) and most pertinently to this thesis, implicit learning of spatial context (Vaidya et al., 2007) correlates positively with age. Therefore, the degree to which results from previous contextual cueing studies on children with autism (Barnes et al., 2008; Brown et al., in revision) can generalise to older ASD individuals is uncertain. Secondly, while there are contradictory findings regarding the independency of implicit learning from IQ, with some studies showing independency (Gebauer & Mackintosh, 2007; Maybery et al., 1995; Reber, Walkenfeld, & Hernstadt, 1991) and others not (Fletcher, Maybery, & Bennett, 2000), the role of IQ cannot be conclusively ignored. In their contextual cueing study, Barnes and colleagues (2008) did not correlate performance in the task with IQ levels and this

analysis would have been important particularly because half of their participants had high-average or superior IQ.

### *2.1.1. Contextual Cueing as an Index of Implicit Learning*

In the general introduction it was emphasized that implicit learning may be distinct from implicit memory and explicit learning while attempts have been made to dissociate their contributions. The authors of the original study (Chun & Jiang, 1998) point out that although implicit learning can produce explicit knowledge, and some forms of explicit learning are only accessible through implicit procedures, contextual cueing is a task that not only produces implicit learning, but memory traces that are also implicit. Indeed, implicit learning in the contextual cueing studies is shown by faster target localization in the repeated configurations, while participants do not realize that they are faster in these trials (no awareness) and although they have not been asked to learn them (no intention). Additionally, memory of these configurations is also implicit as revealed by a recognition test administered at the end of contextual cueing studies, which shows that participants do not show better recognition of the repeated trials than they would do through random guessing.

### *2.1.2. The Choice of Method*

Since the 1960s a range of tasks has been developed to assess implicit learning so it is important to discuss the rationale for the selection of one of these in particular-the contextual cueing task. Some of the standard methods of assessing implicit learning in autism have already been reported in the general introduction and include tasks such as the artificial grammar learning (Reber, 1967), serial reaction time (Nissen & Bullemer, 1987) and probabilistic classification learning task (Gluck & Bower, 1988), as well as tasks of category learning, which is thought to take place implicitly

(Knowlton & Squire, 1993; Smith, in press). The choice of contextual cueing as a measure of implicit learning in ASD was appealing for several reasons.

Firstly, it measures associative learning and spatial context learning which are processes widely researched and very controversial as to whether they are impaired or intact in autism. Secondly, it involves ‘low-level’ perceptual search processes (Smyth & Shanks, 2008) which allow for a robust experimental control of the stimuli while not imposing great demands on participants. Thirdly, the motor coordination demands of this task are limited, since it is not an implicit motor learning task, which would be based on learning of the association between a cue and a motor response, but rather it is based on visual learning of the target-context associations (van Asselen et al., 2009).

The present study employed the contextual cueing task as initially designed by Chun and Jiang (1998). Observers performed visual search on displays of multi-coloured letter arrays, illustrated in Figure 2.1, and responded to the orientation of a target (letter T) that was presented amongst distractor items (letters L). Chun and Jiang (1998) showed that participants became progressively faster to respond to repeated trials compared to novel ones that they had only viewed once. Chun and Jiang (1998) termed this benefit in reaction time *contextual cuing* because they argued that observers encode the spatial configuration of the distractors, which forms the spatial context of the target and this serves as a cue that guides attention to the target location. Although a small number of participants may become aware that certain displays are repeated throughout the experiment, they still show implicit memory as they are not able to recognize them at a rate which is better than chance.

### *2.1.3. Aims and Predictions*

To date, research has not yet investigated implicit learning of spatial context in older individuals with intellectual ability in the average range. Performance of the ASD group was compared to that of a TD group matched for age, verbal and non-verbal ability. Matching of the two groups in terms of intellectual ability was necessary to ensuring that factors such as visuo-motor skills and verbal abilities were developed to a similar extent in both groups enabling them to perform target detection and to understand the instructions equally well. The aim of the present study was to assess implicit learning of spatial context in adolescents and adults with ASD, since previous research may have prevented the finding of significant group differences by examining young children who may not show mature learning of spatial context (Vaidya et al., 2007).

Comparable performance between the two groups would extend previous research of intact implicit learning in children with autism (Barnes et al., 2008) to adolescents and adults with ASD. Enhanced performance in the ASD group, on the other hand, would suggest that older individuals with ASD perform better because of their mature age and a bias to attend to the local context of the target. Finally, in accord with previous research, it is expected that recognition of the repeated displays will be at chance levels.

## **2.2. Method**

### *2.2.1. Participants*

Nineteen individuals (16 males) with ASD aged 17-26 years were recruited from a special college for autism. All had been diagnosed with high-functioning autism or Asperger's syndrome by experienced clinicians according to the Autism Diagnostic

Observation Schedule (ADOS; Lord et al., 1989) and/or the Autism Diagnostic Interview-Revised (ADI-R; Lord, Rutter, & Le-Couteur, 1994). A comparison group of 19 TD individuals (16 males) aged 17-32 years, was recruited from mainstream further education colleges. Participants' mental age was assessed using the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999) and all obtained full-scale IQ (FSIQ) scores which were within the average range ( $IQ > 80$ ). All participants had normal or corrected-to-normal visual acuity and took part in this study as paid volunteers.

Demographic characteristics of the two groups are presented in Table 2.1. The groups were group-wise matched for chronological age,  $t(36) = 0.09$ ,  $p = 0.93$ , verbal IQ,  $t(36) = 0.80$ ,  $p = 0.43$ , non-verbal IQ,  $t(36) = 1.29$ ,  $p = 0.21$ , and full-scale IQ,  $t(36) = 1.27$ ,  $p = 0.21$ .

Table 2.1 Participant demographic characteristics (means with S.D.s in brackets)

Group	Age in years	WASI IQ		
		Verbal	Non-verbal	Full-scale
ASD	20 (3.0)	96.0 (15.5)	99.1 (11.7)	97.7 (10.7)
TD	20 (4.3)	99.7 (12.7)	103.3 (8.1)	101.6 (8.0)

### 2.2.2. Apparatus

Participants viewed the stimuli on a 14-inch colour monitor from an unrestricted distance of about 50cm. Responses were recorded using a two button response box and participants pressed one of the two buttons corresponding to whether the target (horizontal 'T') pointed to the right or to the left.

### 2.2.3. *Stimuli*

The items of the visual search display appeared in an invisible 8 x 6 grid and subtended approximately 37.2 x 28.3 degrees in visual angle. The position of items was jittered to prevent colinearities with neighbouring items. The size of the stimuli and their jittered positions were identical to those used in the original paper (Chun & Jiang, 1998, Experiment 1) and to all the implicit learning experiments presented in this thesis. Examples of displays are depicted in Figure 2.1.

Each display was made up of 12 items (11 distractors and one target) and consisted of an equal number of red, green, blue and yellow items presented against a grey background. The distractor items were L shapes rotated in four orientations (0°, 90°, 180°, or 270°) and presented at randomly chosen locations. The target item was a T rotated 90° either to the left or to the right with equal probability. Twelve target locations were chosen in the repeated displays and the same twelve were used in the novel displays. In this experiment participants were shown a total of 288 trials that were presented in cycles of blocks, with each block comprising 24 trials (12 repeated and 12 novel). Block ordering was counterbalanced, so that half of the participants were presented with blocks 1-12 and the other half with blocks 7-12 followed by blocks 1-6.

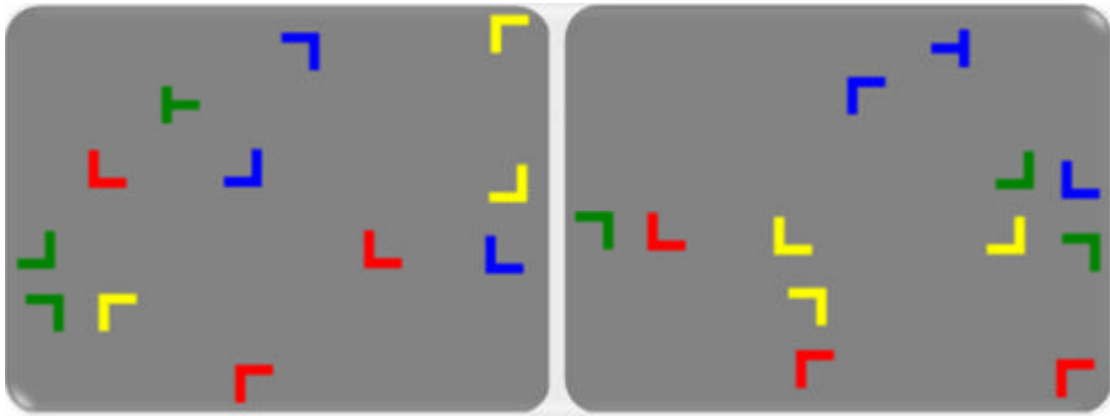


Figure 2.1. Example stimuli of letter arrays containing one target ‘T’ and 11 distractor ‘L’s which form the spatial context of the target.

#### 2.2.4. Design and Procedure

The session started with a practice block of 24 trials to familiarise participants with the task. Following this, participants had to complete 12 experimental blocks and each block contained 24 different displays in random sequence: 12 *Repeated* and 12 *Novel*. The 12 *repeated* displays were repeated throughout the entire experiment once per block and only the orientation of the target changed from one block to the other. The *novel* displays were newly generated for each block to serve as a control baseline. The session concluded with a recognition block of 24 trials (12 repeated, 12 novel). In this phase participants were asked to respond on the basis of whether they thought they had seen each display previously in the experiment and press a “Yes” or a “No” key accordingly.

Although, all participants viewed the exact same displays, pilot studies were conducted to ensure that there was no intrinsic difference in the difficulty of the two conditions at the outset of the experiment. In other words, during the first presentation of the all the different displays, the search time in the two conditions must be



equivalent, so that any differences between the conditions later in the experiment can be attributed to the effect of training rather than to an extraneous variable such as targets in one condition being easier to localize than targets in the other.

### 2.2.5. *Trial Sequence*

The experimenter instructed participants to look at the central pre-trial fixation marker and when the display appeared, then search for a ‘T’ target and respond as quickly and as accurately as possible by pressing either the left or the right button when the orientation of the tail of the ‘T’ was pointing to the left or to the right respectively. Participants pressed the spacebar to initiate each block and at the end of each block, they were allowed to take a break. Each visual search trial began with a 500msec fixation period followed by the search display which remained on the screen until the participant made a response. The duration of the whole experiment was approximately 25 minutes. None of the participants was informed that some displays repeated and no feedback was given for correct or incorrect responses.

## 2.3. Results

### 2.3.1. *Exploratory Data Analysis*

*Assumptions of ANOVA.* Homogeneity of variance was violated according to Levene’s test (Levene, 1960), but due to equal sample sizes this is unlikely to constitute a problem (Cardinal & Aitken, 2006). Normality of distributions was checked using Q-Q plots and the Shapiro-Wilk test (Shapiro & Wilk, 1965). Distribution was positively skewed for some dependent variables, which is expected with RT data (e.g., Whelan, 2008). The sphericity assumption was not violated for any of the variables.

*Data screening.* To reduce the influence of outliers we experimented with different cut-off points, but this method resulted in the removal of too many data

points. Thus, consistent with other contextual cueing studies (e.g, Barnes, Howard, Howard, Kenealy, & Vaidya, in press; Jiang & Wagner, 2004), we used the mean of median reaction time which yielded two advantages. Firstly, the number of outliers was effectively reduced and even when some appeared they did not significantly influence the results. Secondly, all data points were retained, as the effect of extreme values becomes almost insignificant when the median is used. Also, consistent with other studies (e.g., Chun & Jiang, 1998, 1999) we averaged the RTs of six blocks into an epoch as a means to increase the statistical power. Thus, we created 2 epochs by grouping the first six blocks (Epoch 1) and the last six blocks (Epoch 2).

*Effect size.* We report the partial eta-squared ( $\eta_p^2$ ) coefficient instead of the eta-squared ( $\eta^2$ ) because although it can be more difficult to interpret since its value is not additive and can therefore sum to more than one (Cardinal & Aitken, 2006), however its value depends only on the independent variable of interest and not on the number and significance of other independent variables as it happens with eta-squared ( $\eta^2$ ) (Tabachnick & Fidell, 2007). Of course, the general flaw with eta squared effect sizes is that they are only accurate when applied to populations and not samples like the ones used in here (Cardinal & Aitken, 2006). Although the omega-squared effect size would be a good alternative in that it takes sample size into account, SPSS does not calculate it and it is ‘laborious to calculate by hand’ (Cardinal & Aitken, 2006, p. 214). Finally, Cohen’s *d*, was not used as we performed more complex comparisons than just the differences between two standardised means for which case *Cohen’s d* statistic is used (Tabachnick & Fidell, 2007).

### 2.3.2. Data Analysis Procedures

*Accuracy.* In line with previous research (e.g., Chun & Jiang, 1998) trials were excluded from analysis if a response was incorrect. Overall, accuracy was high (99%

and above) and was not significantly affected by group,  $F(1,22) = 2.71, p = 0.11$ , condition,  $F(1,22) = 1.205, p = 0.28$ , or block,  $F(1,47) = 1.58, p = 0.15$ .

*Reaction Time.* Figure 2.2 illustrates the mean of median RT as a function of epoch and condition. The median RT for all correct trials was analyzed using a three-factor mixed ANOVA with two within-subjects factors (Epoch: 1<sup>st</sup>, 2<sup>nd</sup>; Trial-Type: Repeated, Novel) and one between-subjects factor (Group: ASD, TD). As in previous contextual cueing studies (Barnes et al., 2008; Brown et al., in revision), the main effect of group was significant, because the ASD group was overall slower than the TD group,  $F(1,36) = 5.80, p < .05, \eta_p^2 = 0.14$ , which suggests that the ASD group found the task more effortful. There was a main effect of epoch,  $F(1,36) = 121.37, p < .00001, \eta_p^2 = 0.77$ , as participants became faster over time due to perceptual/skill learning (Chun & Phelps, 1999; Schneider & Shiffrin, 1977). Specific learning of the repeated displays—contextual cueing—was revealed by a significantly improved RT performance in the repeated than in the novel condition,  $F(1,36) = 24.49, p < .0001, \eta_p^2 = 0.405$ .

Unlike previous contextual cueing studies, there was not an interaction of trial-type and epoch ( $F < 1$ ) to suggest that in the first epoch participants were equally fast between the two trial-types, but in the second epoch the difference between the two conditions became significantly different as a result of learning. However, there was a marginally significant 3-way interaction of group, trial-type and epoch,  $F(1,36) = 3.13, p = .085, \eta_p^2 = 0.08$ . In order to establish the source of this interaction, pair-wise comparisons using Bonferroni adjustment for family-wise errors were performed. These indicated the expected results for the TD group with no difference between trial-types in the first epoch ( $m = 27\text{ms}, p = .21$ ) and a significant difference between the trial-types, i.e., contextual cueing, in the second epoch ( $m = 67\text{ms}, p = .005$ ).

However, the ASD group showed the opposite pattern with faster target detection in repeated compared to novel trials in the first epoch ( $m = 77\text{ms}$ ,  $p = .001$ ), but not in the second epoch ( $m = 37\text{ms}$ ,  $p = .11$ ). Thus, for some unexpected reason the ASD group showed a significant difference between repeated and novel trials very early in the experiment, but after that showed no sign of significant contextual cueing.

To ensure that there were no differences very early in the experiment, a mixed ANOVA with one within-subjects factors (Trial-Type: Repeated, Novel) and one between-subjects factor (Group: ASD, TD) was performed on the data of the first block. Results showed that search times were not significantly different between the two trial-types,  $F(1,36) = 1.66$ ,  $p = .21$ ,  $\eta_p^2 = 0.04$  and there was no interaction of group with trial-type,  $F(1,36) = 1.805$ ,  $p = .19$ ,  $\eta_p^2 = 0.05$ . Despite the non-significant group x trial-type interaction, the ASD group tended to detect targets faster in the repeated than the novel condition by on average 120 ms ( $p = 0.07$ ), while the TD group showed no such difference ( $p = 0.97$ ) (See Appendix 2.1 for a group by block by trial-type illustration). Thus, the ASD group did show a better discrimination for targets in the repeated trials compared to novel trials during the first block, which was more significant than that of the TD group.

As proposed by Barnes and colleagues (2008), in order to determine whether the overall slower search times of the ASD group influenced the magnitude of contextual learning (the difference in search time between the two trial types), we took measures of proportional learning for each participant (the difference in search time between the two trial-types divided by the mean search time on novel trials). This measure equated speed by expressing learning as a proportion of one's baseline speed. We found that this proportional learning was not different in the two groups,  $F(1,36) = 1.92$ ,  $p = .17$ , which suggests the magnitude of contextual learning was not

different in the two groups even when we controlled for differences in overall reaction time, although it tended to be greater in the TD than the ASD group.

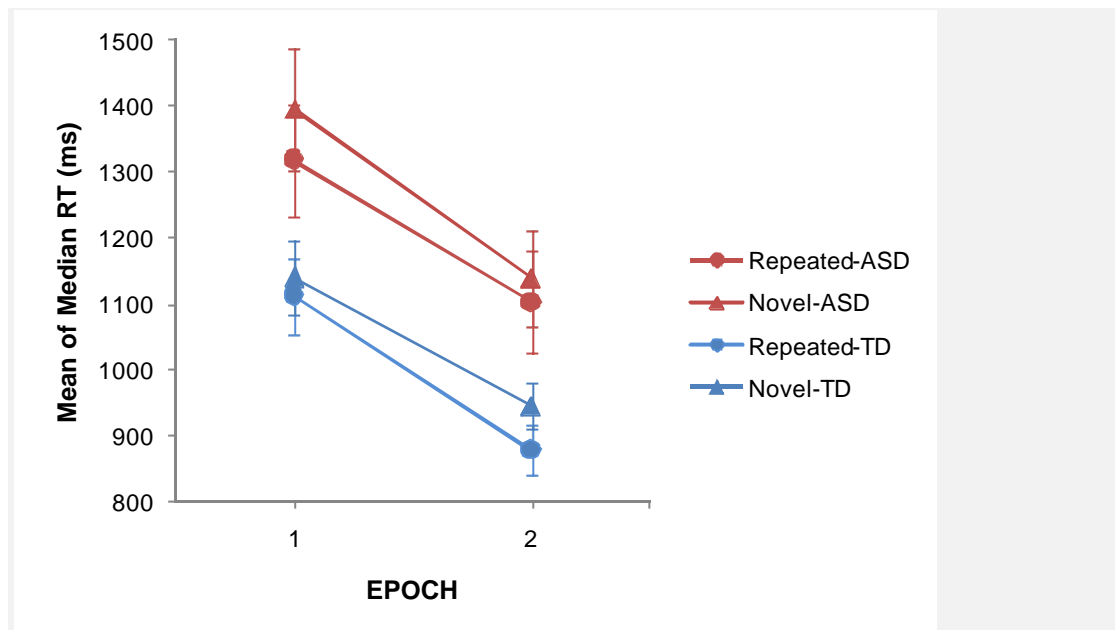


Figure 2.2. Mean of median reaction time (in milliseconds) across the 2 conditions as a function of epoch (one epoch = 6 blocks) and group.

Error bars show the standard error of the mean. Overall, the repeated condition shows additional learning compared to the novel condition. As expected, the TD group shows contextual cueing only in the second epoch, while the ASD group shows an early and atypical benefit in search time of the repeated trials in the first epoch.

*Recognition Phase.* To establish whether participants had implicit memory of the repeated displays, the correct identification of the repeated displays as previously seen (hit rate) must not be significantly higher than the incorrect identification of the novel displays as previously seen (false alarm rate). A separate repeated measures ANOVA for each group with one within-subjects factor (Rate: Hit, False Alarm) was

performed. Findings showed that while for the TD group the Hit Rate was slightly but significantly higher than the False Alarm Rate,  $F(1,18) = 6.25, p < .05, \eta_p^2 = 0.26$ , (Hit: 59 %, False Alarm: 48 %), for the ASD group there was no such difference, [ $F < 1$ , (Hit: 48 %, False Alarm: 43 %)]. Furthermore, an unpaired t-test indicated that the difference between the two rates did not differ significantly between the two groups,  $t(36) = 0.98, p = .33$ . Thus, while the ASD showed implicit memory of context, some participants in the TD group showed a degree of awareness and so memory representations of context may not have been implicit for all TD participants.

To examine whether the awareness of the TD group may have influenced the magnitude of contextual cueing, a novel method of analysing recognition data was adopted from a recent study (Preston & Gabrieli, 2008). Firstly, for each participant measures of corrected hits (the difference between hit rate and false alarm rate) were taken, and then via a binomial test, it was determined what the chance performance was on the recognition test (i.e., how many items a person would have to get correct to perform above chance). Based on this statistic, participants subsequently were assigned to the 'aware' or 'unaware' group.

To calculate the level of above chance performance a Binomial test was used. Firstly, the expected number of hits was calculated by multiplying the number of corrected hits with the probability of the result ( $N * p = 12 * 0.5 = 6$ ) and its standard deviation was calculated by the square root of  $N * p * (1 - p)$  which gives square root of  $(12 * 0.5 * 0.5) = 1.73$ . A number of corrected hits more than 2 standard deviations from the expected number should only occur by chance on 5% of occasions. Hence, we used this value ( $2 * 1.73 = 3.46$ ) to evaluate whether recognition performance was above chance. Thus, any participants who had a corrected hit equal to or above 4 were assigned to the 'aware' group otherwise were assigned to the 'unaware' group.

The analysis was confined to the TD group as it was the only group to show evidence of awareness. Only 5 out of nineteen TD participants were assigned to the ‘aware’ group and had a hit rate that was significantly higher from their false alarm rate,  $F(1,3) = 120.27, p < .01, \eta_p^2 = 0.98$ , whereas the two rates did not differ in the ‘unaware’ group,  $F(1, 14) = 1.00, p = .33, \eta_p^2 = 0.07$ . To examine whether the classification into above (aware group) or below (unaware group) chance recognition influenced the magnitude of contextual cueing an ANOVA with one within-subjects factor (Trial-Type: Repeated, Novel) and one between-subjects factor (Recognition: Aware vs Unaware) was performed on the data of the second epoch in which learning effects are more apparent. The interaction between the two factors was not significant,  $F(1, 17) = 1.53, p = .23, \eta_p^2 = 0.08$ , which indicated that context learning was not modulated by above chance recognition of the repeated displays and this finding is consistent with previous findings (Preston & Gabrieli, 2008; Smyth & Shanks, 2008).

To further investigate the association between recognition memory and magnitude of contextual cueing in both groups, Pearson’s correlation coefficients were calculated between corrected hits and magnitude of contextual cueing (the difference in speed between the two trial-types). As expected, there was no correlation between recognition memory and contextual cueing for either the ASD, Pearson’s  $r = .13, p = .60$ , or the TD group, Pearson’s  $r = -.21, p = .39$ . While, a null correlation does not necessarily imply functional independence this result is consistent with previous research (Preston & Gabrieli, 2008).

*IQ and learning analysis.* Pearson’s correlation coefficients were calculated to assess whether differences in chronological age, nonverbal ability and verbal ability were associated with the magnitude of contextual cueing. Pearson’s correlations revealed no reliable associations between learning scores and the above measures

even when correlations were performed separately for the ASD (range of Pearson's  $r = -.07$  to  $-.18$ ,  $n = 19$ ,  $ps = .44$ ) and the TD group (range of Pearson's  $r = .20$  to  $.34$ ,  $n = 19$ ,  $ps = .16$ ). This suggests that in the present study, implicit learning was independent of IQ.

### 2.4. General Discussion

#### 2.4.1. *Summary of Results*

Experiment 1 aimed to investigate whether implicit learning of spatial context was preserved in a group of young adults with ASD. The ASD group was found to show reduced context learning in the second half of the experiment, while initially they showed superior context learning. However, superior contextual cueing in the first epoch may not have resulted from learning of the repeated trials, because faster search times in the repeated than the novel trials were found even from the first block. Also, the design of the study may have prevented a better performance from the ASD group because it did not encourage local processing, as the intermixing of repeated and novel trials in each block, meant that local context was not consistently associated with success. Recognition memory in the ASD group was implicit and while a small percentage of TD individuals showed explicit memory, their explicit recognition memory did not appear to influence their magnitude of learning. Also, IQ did not mediate magnitude of learning which suggests that in this task implicit learning was most probably independent of IQ level.

#### 2.4.2. *Relation to Previous Findings*

The current finding of atypical early contextual learning in ASD complements that of a recent study (Brown, Aczél, Jiménez, Kaufman, & Plaisted-Grant, 2009) which was carried out after the current experiment was completed. Brown et al. (2009) presented



children with ASD with a hybrid task in which sequence information was embedded within the contextual cueing task. Similarly, to the evidence of the present study, they also found that in the first two blocks the TD group showed no context cueing, whereas the ASD group did. The authors concluded that children with ASD showed an early and atypical superior contextual cueing.

However, whereas in Brown et al. (2009) the search time difference between the two conditions in the very first block was less than 20ms, in the present experiment it was just below 120ms. Thus, it is unlikely that the present result deserves the same interpretation as Brown et al.'s (2009) study. Instead, it points to perceptual atypicalities in ASD that may have served to enhance surface features, such as the color distribution of the items, with subsequent effects on their ability to discriminate targets in the repeated trials more easily than targets in the novel trials during the first half of the experiment. However, in the second half of the experiment the difference in search times between repeated and novel trials was reduced. Since, both types of trials shared the same target locations, it is possible that as the experiment progressed, the ASD group somehow adapted to the task, and their search time was mostly influenced by the location of the target rather than other factors.

The finding that the autism group was overall slower in the majority of the experimental phases is consistent with Barnes and colleagues (2008), but not with recent evidence of superior performance in visual search tasks (O'Riordan & Plaisted, 2001; O'Riordan et al., 2001; Plaisted et al., 1998b). However, certain methodological differences between the present studies and those that reveal superior performance could account for the discrepancies between the results. In contrast to the above studies, participants in the present studies received no feedback on either the speed or the accuracy of the response. Also, the present task was to decide whether the target

pointed to the left or to the right rather than whether the target was present or not. Most importantly, as the authors point out (O'Riordan & Plaisted, 2001), superior performance in the autism group was often found only in target-absent trials, whereas in our experiment the target was always present.

### *2.4.3. Critique of Method*

Recent studies with typical populations have challenged the notion of implicitness in the contextual cueing task by showing that a degree of awareness exists (Preston & Gabrieli, 2008; Smyth & Shanks, 2008). More specifically, Smyth and Shanks (2008) claimed that previous contextual cueing studies have not employed powerful and reliable tests of awareness. Thus, when Smyth and Shanks (2008) increased the power of the recognition test by adding a greater number of trials they found that some context information was consciously retrievable. However, it is possible that context information is consciously retrievable after implicit learning has taken place. To rule out this possibility the authors carried out another experiment in which the recognition trials were administered concurrently with the target detection trials. The findings confirmed that participants could recognize some repeated configurations explicitly. But, importantly, in both studies (Preston & Gabrieli, 2008; Smyth & Shanks, 2008) the contextual learning was obtained regardless of whether participants demonstrated any awareness, and the magnitude of learning was also not related to whether a display was available to awareness. Thus, although some awareness may exist this does not seem detrimental to the hypothesis that implicit learning is driving contextual cueing.

### *2.4.4. Conclusions and Next Steps*

In the present experiment we did not find evidence for preserved implicit learning in the ASD group. This is inconsistent with previous research on contextual cueing in

children with ASD (Barnes et al., 2008; Brown et al., in revision; Brown & Plaisted, 2008). One possibility is that implicit learning in ASD is intact, but atypical early differences at the beginning of the experiment, interfered with acquiring learning of the spatial context later in the experiment. The finding of unexpected early differences, pointed to the need for an improved counterbalancing in the future implicit learning experiments of the current thesis. An alternative possibility is that the lack of learning in the ASD group, represented difficulties in their ability to create target-context associations rather than difficulties in implicit learning of context per se. The aim of the next two experiments (Chapter 3) was to separate these two contributions, by investigating target-context associations in a contextual cueing task that relied on explicit rather than implicit learning.

### 3. CONTEXTUAL CUEING AND EXPLICIT LEARNING OF VISUOSPATIAL CONTEXT

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#### 3.1. Introduction

Experiment 1 revealed that, in an implicit learning contextual cueing task, individuals with ASD appeared not to benefit to the same extent as a control group, from spatial layouts that were repeated without their awareness. It is worth exploring then, whether this reduced performance generalises to a contextual cueing task in which the repeated spatial layouts are readily recognised. This explicit version of the contextual cueing task was developed by using realistic scenes rather than letter arrays, such that the target location was paired with a particular scene resulting in explicit learning of the association (e.g., Brockmole, Castelhano, & Henderson, 2006; Brockmole & Henderson, 2006a, 2006b; Summerfield, Lepsien, Gitelman, Mesulam, & Nobre, 2006). The purpose of the two experiments presented in this chapter was to explore whether explicit learning and memory of context was typical in a group of adolescents and adults with ASD.

It is important to explore whether explicit learning is typical in autism, not only because of the reason outlined above, but also because the current view is that explicit learning is related to how individuals with autism perform in implicit learning tasks. For instance, it has been suggested that individuals with autism use explicit learning as a compensatory mechanism for their deficits in implicit learning and episodic memory (Ben Shalom, 2003; Gidley-Larson, Bastian, Donchin, Shadmehr, & Mostofsky, 2008; Klinger et al., 2007; Mostofsky et al., 2000; Walenski, Mostofsky, Gidley-Larson, & Ullman, 2008). Brown and colleagues (in revision) proposed not a compensatory but rather a competitive link between the two, according to which

overuse of explicit learning strategies may interfere with one's ability to learn implicitly. Additionally, the special case of savant abilities in autism is also considered to develop through an amalgamation of implicit and explicit contributions rather than a unique contribution of one of them (Miller, 1999). Finally, much of the intervention programmes in autism have been developed on the understanding that individuals with autism need to be taught all behaviours in an explicit mode (Dawson et al., 2008), thus assuming that behaviors cannot be learned implicitly.

### *3.1.1. Explicit Learning of Repeated Material in Autism*

The experiments reported here are the first of explicit learning and memory in ASD, using the contextual cueing paradigm and so a background of how individuals with ASD perform on other tasks of explicit acquisition of repeated material is necessary. But, firstly, the theoretical framework which inspired research in memory functioning in autism is briefly discussed.

Research in explicit memory was sparked by the hypothesis that autism is best characterized as an amnesic disorder. Boucher and colleagues (Boucher, 1981; Boucher & Warrington, 1976) were the first to show that autism shares similar explicit memory deficits as people with amnesia. Experiments on newborn monkeys which showed that the development of medial temporal amnesia resulted in patterns of behavior similar to autism (Bachevalier, 1994) led to the proposal that autism can be described as an amnesic disorder with temporal lobe dysfunction. More specifically, the extent of damage to medial temporal lobe structures was related to the severity of socio-emotional and memory disturbance in the monkeys. However, as will be seen below, empirical research did not support this hypothesis.

Explicit learning of repeated material in autism has been studied using both verbal and visual tasks. In the verbal domain, intact priming repetition effects in children with ASD have been reported (e.g., Renner, Klinger, & Klinger, 2000; Salmond et al., 2005). In the visual domain, individuals with ASD also seem able to explicitly learn repeated information (Klinger & Dawson, 2001). In memory studies of repeated material preserved explicit semantic memory (e.g., Ben Shalom, 2003; López & Leekam, 2003; Salmond et al., 2005; Siegel, Minshew, & Goldstein, 1996) and recognition memory (e.g., Bennetto, Pennington, & Rogers, 1996; Brian & Bryson, 1996) has also been reported.

This is not to say that memory functioning is typical in autism. For instance, selective deficits in recognition memory have been reported but seem to be restricted to individuals with low-functioning autism (Boucher & Warrington, 1976), when face stimuli (Ellis, Ellis, Fraser, & Deb, 1994; Klin et al., 1999) or stimuli of potential agents are used (Blair, Frith, Smith, Abell, & Cipolotti, 2002) in episodic memory (Bowler, Gardiner, & Grice, 2000) and in free recall of verbal material (Bowler, Matthews, & Gardiner, 1997). It can be expected then that at least in high-functioning autism and Asperger's syndrome semantic recognition memory and learning of non-social repeated material is preserved.

### *3.1.2. Contextual Cueing as an Index of Explicit Learning*

In order to explore the role of explicit learning and memory on the deployment of attention, research on contextual cueing has replaced artificial letter arrays for stimuli of scenes. A scene, may be defined as “*a semantically coherent, nameable view of an environment, composed of multiple discrete objects*” (Nijboer, Kanai, de Haan, & van der Smagt, 2008, p. 742). Scenes that have been used in research depict both indoors spaces, such as a living room, as well as outdoors spaces such as a mountain.

Learning of the repeated scenes appears explicit because although there is no intention to learn, observers are aware that they react faster to these previously seen scenes than scenes that are viewed only once.

Recent research has empirically demonstrated that contextual cueing of real-world or realistic scenes is due to explicit recognition memory, as observers are able to recognise the repeated scenes significantly better than chance (Brockmole & Henderson, 2006b; Hollingworth, 2009; Summerfield et al., 2006). It also appears that *semantic* memory in particular facilitates cueing, because when scenes are inverted and therefore more difficult to interpret, they require almost double the amount of repetition compared to upright scenes in order to produce maximal learning (Brockmole & Henderson, 2006b). Also, contextual cueing in inverted scenes is reduced, compared to upright scenes, which supports further the claim that explicit memory drives contextual cueing in scene stimuli. Brockmole and Henderson (2006b) concluded that memory encoding in scene stimuli is explicit rather than implicit and that when semantic information can be extracted and retained this can speed the process of learning.

### *3.1.3. Explicit vs Implicit Contextual Cueing*

Like the implicit contextual cueing task, faster search time in repeated scenes compared to novel scenes, depends on the development of a recognition memory which allows an incoming configuration to match a memory representation acquired through repeated exposure, resulting in more efficient deployment of visual attention and faster target localisation (Brockmole & Henderson, 2006a; Chun & Jiang, 1998). However, given that scene stimuli convey two types of information, i.e., scene identity and local features, an interesting question is which of the two is recognised first or whether they are both recognised at the same time. Brockmole and Henderson

(2006a) investigated this question by mirror-reversing the scenes that had already been learned, so that the scene identity was preserved but the location of the target was misplaced. Findings showed that observers firstly moved their eyes to the position of the display in which the target had previously appeared and then the eyes moved to the new location of the target. The authors concluded that observers firstly recognise the scene identity without a reference to the arrangement of the visual features and then the featural-local information is recognised. This study also highlighted that a repeated context can guide attention more efficiently than a novel context, even if its target's location appears misplaced.

The explicit version of the contextual cueing task differs from its parallel task of implicit learning in a number of ways. Firstly, when letter arrays are used tens of repetitions need to take place before learning is observed (Chun & Jiang, 1998), whereas with scene stimuli a handful of repetitions is sufficient for contextual cueing to develop fully (Becker & Rasmussen, 2008; Brockmole & Henderson, 2006b). Secondly, scene recognition occurs very fast, within 100ms of viewing (e.g., Brockmole & Henderson, 2006a; Potter, 1976) whereas recognition in letter arrays does not even take place in most trials (Peterson & Kramer, 2001). Thirdly, the efficient recognition that scene stimuli attract, increases the speed with which learning takes place and the magnitude of learning itself (Brockmole & Henderson, 2006b). For instance, Brockmole and Henderson (2006b) found that scene-target associations were learnt up to 5 times faster and produced 20-25 times greater magnitude of learning compared to contextual cueing studies of artificial stimuli. However, in the same study it was also found that search times in the novel trials do not become faster over time as they do in stimuli of letter arrays, which suggests that in scene stimuli

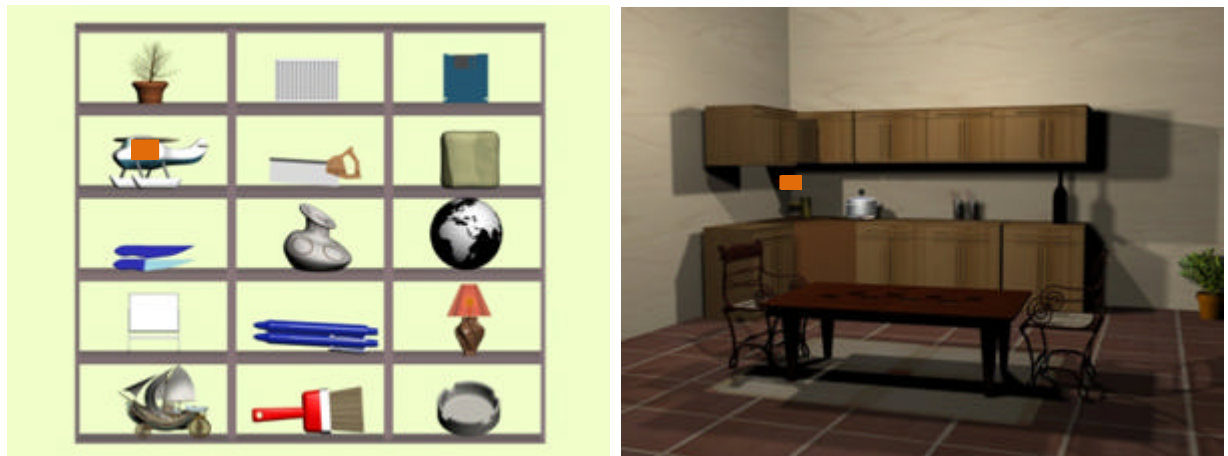
Chun</Author><Year>2000</Year><RecNum>38</RecNum><record><rec-



stimuli may result in a slower serial processing of novel stimuli in particular, as search in this type of stimuli is not memory-based, but perception-based. Finally, and most importantly, in the implicit contextual cueing tasks observers learn to associate the target with the local rather than the global context (Brady & Chun, 2007; Olson & Chun, 2002), whereas as described above, in the explicit contextual cueing tasks observers learn to associate the target with the global context and only use the local when the global context is not predictive of the target location (Brockmole et al., 2006).

### *3.1.4. The Choice of Method*

The present study developed two experiments of contextual cueing to study target-scene associations in ASD (see Figure 3.1). Experiment 2 employed stimuli that were termed ‘intermediate coherence’ scenes and consisted of cabinet scenes in which individual real-world items were randomly allocated to different locations of the display. Experiment 3, employed stimuli that were termed ‘high coherence’ scenes and consisted of realistically rendered scenes that depicted indoors areas such as kitchens and living rooms. This latter type of stimuli corresponded to the standard method of assessing explicit learning in a contextual cueing task, while the intermediate coherence scenes were developed here for the first time.



*Figure 3.1.* Example stimuli of the ‘intermediate coherence’ scenes used in Experiment 2 (left panel) and the ‘full coherence’ scenes used in Experiment 3 (right panel).

To illustrate the location and size of the target, orange rectangles have been added. The markers used here are not the same as the actual search targets.

The inclusion of two experiments instead of one was necessary for two reasons. Firstly, in light of results that scene identity is recognised and guides attention faster (Brockmole & Henderson, 2006a) than visual features, the aim was to develop a novel way of separating the contributions of scene identity vs visual features, by creating two experiments that differed in the type of information (scene identity or features) that were more readily available. In Experiment 2, the scene identity was always the same (a cabinet of objects) while the constituent parts changed, whereas in Experiment 3 the scene identity was different across the displays. As a result, visual features rather than scene identity would be more useful attentional cues in Experiment 2, whereas scene identity would be a more useful attentional cue in Experiment 3. In accord to evidence that the scene identity is recognised faster, compared to constituent parts (Brockmole & Henderson, 2006a) it is can be expected

that search times will be faster in Experiment 3 in which scene identity is a more useful cue, compared to Experiment 2.

Secondly, the intermediate version of the contextual cueing task, was developed for the first time in the present study and represented an ‘intermediate’ level between two ends of a continuum from wholly abstract stimuli of letter arrays (low coherence) used in Experiment 1, to wholly semantic stimuli of real-world scenes (high coherence) used in Experiment 3. More specifically, the intermediate coherence scene stimuli depicted individual objects, thus sharing the same structure available in experiments of stimulus arrays, but because these objects were real-world objects, they also shared the semantic nature of stimuli available in experiments of real-world scenes. The idea of the intermediate version was inspired by the stimuli depicting cabinets of objects, that were used in a non-contextual cueing study, investigating the relationship between fixation duration and saccade amplitude during the presentation of scenes (Unema, Pannasch, Joos, & Velichkovsky, 2005).

### *3.1.5. Explicit Learning and Individual Differences*

There is only one contextual cueing study of scene stimuli which has investigated how performance in this task may be influenced by individual differences (Jiang, King, Shim, & Vickery, 2006). Jiang and colleagues (2006) examined college students in a contextual cueing task using real-world scenes and in a range of IQ measures from word memory and spatial abilities to visual working memory and task switching. The choice of these measures was primarily based on the knowledge that they are supported by the same neural substrates, i.e., the medial temporal lobes, which are also known to support spatial context learning (Chun & Phelps, 1999). However, no significant correlations were found between any of these measures and learning in the contextual cueing task. This may appear surprising, given that non-contextual cueing

studies have shown that explicit learning depends on IQ (e.g., Gebauer & Mackintosh, 2007; Maybery et al., 1995) and explicit memory follows a developmental trajectory such that it improves with age (Ofen et al., 2007). However, as Jiang and colleagues (2006) note, the limited range of tasks may have prevented the finding of significant correlations and point to the need for future research to increase test-retest reliability of the contextual cueing effect, before cognitive skills can be correlated with it.

### 3.1.6. *The Three Forms of Learning*

In both experiments observers searched for letter targets embedded in displays of realistic scenes. Following typical contextual cueing procedures, intermixed in each block there were scenes presented that had not previously been shown (*Novel*) and scenes which were repeatedly presented across blocks (*Repeated*). A third condition was added, in which the background scene was repeated but the target embedded in it changed location across blocks (*Variable*).

In the repeated condition both the scene context and the target are repeated across blocks, which results in a form of *associative learning* between the scene context and its target location. Instead, in the variable condition the repeated scene context does not predict the target's location and so it can only produce *familiarity effects* rather than associative learning. Thus, by comparing search time in the repeated trials (scene familiarity + associative learning) with search time in the variable trials (scene familiarity-associative learning) a more pure measure of associative learning can be obtained (Jiang et al., 2006). In the novel condition improved visual search is due to *perceptual/skill learning* only and this develops with training. Search times in the repeated and variable conditions also become faster partly as a result of perceptual/skill learning (Chun & Jiang, 1998).

### *3.1.7. Aims and Predictions*

The present study explored contextual cueing of repeated scenes in a group of adolescents and adults with ASD and a group of TD individuals matched as far as possible on gender, chronological age and nonverbal ability. The first aim concerned whether contextual cueing of scenes was comparable in the two groups. It was predicted that the adolescents and adults of this ASD group will show preserved recognition memory of repeated material. However, if there is a specific difficulty in associating a target with its repeated context, then learning in the ASD group will be reduced compared to the TD group and such a finding would point to a reduced top-down modulation of attention.

The second aim was to directly compare the two experiments. If search time in the high coherence scenes is faster than that of the intermediate coherence scenes, then this would suggest that high coherence scenes are associated more strongly with attention to the global context (scene identity), whereas the intermediate coherence scenes with attention to the local context (individual objects). Another prediction that follows is that if individuals with ASD show a superior processing of local rather than global information, they will show relatively better performance in the intermediate coherence scenes compared to the full coherence scenes.

The third aim concerned the comparison of search time in the different conditions. It was predicted that participants will show repetition facilitation and thus, react faster to repeated and variable conditions than the novel condition. Additionally, it was expected that the associative learning produced by the repeated condition will yield greater search time benefits than the familiarity effects produced by the variable condition. Finally, it was expected that search time in the novel trials will not improve with training in these scene stimuli.

The fourth aim was to replicate the finding that recognition memory is explicit and so it was expected that participants will show above chance performance on the recognition task, confirming that conscious memory processes can account for the repetition facilitation effects in scene stimuli.

### 3.2. General Methodology

#### 3.2.1. *Participants*

Seventeen individuals (13 males) with high-functioning autism/Asperger's syndrome aged 17-25 years were recruited from the same special college for autism as reported in chapter 1 on page 37. Five ASD participants had also taken part in Experiment 1. A comparison group of 16 TD individuals (12 males) aged 16-22 years, was recruited from mainstream further education colleges. Participants in this experiment obtained FSIQ within the average range ( $IQ > 80$ ), had normal or corrected-to-normal visual acuity and took part in this study as paid volunteers.

Demographic characteristics of the two groups are presented in Table 3.1. The groups were group-wise matched for chronological age,  $t(31) = 0.89$ ,  $p = 0.38$ , as well as non-verbal IQ,  $t(31) = 1.01$ ,  $p = 0.32$ . However, the ASD group had lower verbal IQ,  $t(31) = 2.82$ ,  $p = 0.01$ , which is consistent with their diagnostic criterion of communication impairments. As a result, the full-scale IQ was significantly different between the two groups,  $t(31) = 2.40$ ,  $p = 0.02$ .

Table 3.1 Participant demographic characteristics (means with S.D.s in brackets)

Group	Age in years	WASI IQ		
		Verbal	Non-verbal	Full-scale
ASD	19 (2.4)	95.2 (16.1)	101.7 (11.7)	98.1 (12.3)
TD	20 (1.9)	109.6 (12.9)	106.1 (13.0)	108.2 (14.7)

### 3.2.2. Apparatus

Participants viewed the stimuli on a 14-inch colour monitor from an unrestricted distance of about 50cm. Stimuli were developed using 3D Studio Max (Kinetix, USA), a 3-D modeling program that allowed the rendering of realistic objects and indoors scenes. Some parts of the stimuli were sourced from the internet, but each display as a whole was developed by the experimenter. The target was a red outline of a letter ‘T’ rotated 90° either to the left or to the right with equal probability and *superimposed* on one of the objects of each search display. An example of a display used in Experiment 1 and Experiment 2 is shown in the left and right panel of Figure 3.1 respectively. In order to make the two experiments comparable in terms of the amount of information that they displayed, we aimed to include fifteen objects in the display of each experiment. All testing was conducted over the course of a single approximately one-hour session.

### 3.2.3. Design

The order of the two visual search tasks was counterbalanced across groups and both tasks were completed in the same session, interleaved by measures of IQ. Each session started with a practice phase of 24 trials, followed by the experimental phase of the two tasks and concluded with the recognition phase. The recognition phase was completed only on that experiment which was carried out last, thus just half of the

participants completed the recognition phase of each experiment. All participants viewed the exact same displays and so the target locations and the background scenes were not counterbalanced across participants<sup>2</sup>. It was very time-consuming to produce more displays in order to counterbalance the stimuli, but extensive pilot studies ensured that there was no intrinsic difference in the difficulty of the conditions at the outset of the experiment. The number of pilot studies was considerably larger in the current experiments, compared to that carried out for chapter 2, because of the additional experimentation that was needed to achieve the suitable size and location of the target which would prevent search times from being too fast or too slow.

### 3.2.4. *Trial Sequence*

Trial sequence was identical to that of Experiment 1. Very briefly, participants were instructed to look at the central pre-trial fixation marker and respond to the orientation of the target once the display appeared on the screen.

## 3.3. Experiment 2

The aim of Experiment 2 was to assess explicit learning in ASD by examining whether target detection is facilitated as a result of learning to associate a target with its surrounding visual context. The stimulus set consisted of rendered illustrations of real-world cabinet scenes and was developed in such a way that the constituent objects were more informative than the scene identity.

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<sup>2</sup> Counterbalancing of the stimuli has also not been reported in other relevant studies (Brockmole et al., 2006; Brockmole & Henderson, 2006a, 2006b)



### 3.3.1. Method

#### 3.3.1.1. Stimuli

The search display depicted a grey cabinet against a green background with 15 objects embedded in it. Each scene included a single 'T' presented in 19-point Arial font which constituted the target. The target was equiprobable in all the 15 positions. In addition, we controlled for target location between the 3 different regions (corner, sides, centre) across each of the three trial types. Also, an attempt was made to superimpose half of the targets on lighter and half on darker coloured objects.

#### 3.3.1.2. Design and Procedure

Each visual search task was divided into an experimental phase and a recognition phase. In the *experimental phase* participants were presented with 5 blocks of 24 trials. Within each block there were, randomly intermixed, 8 repeated, 8 variable and 8 novel trials. In a repeated trial both the background scene and the target position were repeated across blocks and only the target's orientation was randomly selected in each repetition. In a variable trial the background scene was repeated, but the target's position was varied across blocks. In a novel trial neither the background scene nor the target position were repeated, so the displays were newly generated to measure baseline search speed.

In the *recognition phase*, participants viewed 1 block of 24 trials (8 repeated, 8 variable, 8 novel) and were asked to determine whether each of these displays was previously seen by pressing either a YES or a NO button on the response button box. This phase was included to assess whether memory in this experiment was indeed explicit.

### 3.3.2. Results

#### 3.3.2.1. Exploratory Data Analysis

*Assumptions of ANOVA.* Homogeneity of variance was violated for most of the variables according to Levene's test (Levene, 1960), but due to balanced sample sizes this is unlikely to constitute a problem (Cardinal & Aitken, 2006). In contrast to experiments of letter arrays presented in this thesis, the homogeneity of variance was more severely violated in this experiment using scene stimuli. Thus, dependent variables were subjected to a reciprocal transformation, which is appropriate for reaction times (Cardinal & Aitken, 2006) and this transformation succeeded in removing heterogeneity of variance. Inspection of results showed that transformed and untransformed data were similar and so statistical analyses presented in this section were based on the latter. Normality of distributions was checked using Q-Q plots and the Shapiro-Wilk test (Shapiro & Wilk, 1965). Distribution was positively skewed for some dependent variables, which is expected with RT data (e.g., Whelan, 2008). The sphericity assumption was not violated for any of the variables.

*Data screening.* As in Experiment 1, the influence of outliers was reduced by using the mean of the median RT. Each epoch represented the averaged RT of two blocks. Thus, we created 2 epochs by grouping the first two blocks (Epoch 1) and the last two blocks (Epoch 2).

#### 3.3.2.2. Data Analysis Procedures

*Accuracy.* Overall, accuracy was high and was not significantly affected by block, group or condition (all  $F_s < 1$ ). Trials were excluded from the analysis if they were given an incorrect response (less than 1% for each group) or exceeded 20 seconds (0%). The excluded trials were more or less evenly split between the groups.

*Reaction Time.* Figure 3.2 illustrates the mean of median RT as a function of epoch, trial-type and group. In the first block of the experiment there were no search time differences between the three conditions ( $F < 1$ ) (See appendix 3.1. for a group by block by trial-type illustration). Mean of median RT was analyzed using a three-factor mixed ANOVA with two within-subjects factors (Epoch: 1<sup>st</sup>, 2<sup>nd</sup>; Trial-Type: Repeated, Variable, Novel) and one between-subjects factor (Group: ASD, TD). As participants had not been well matched, Full Scale IQ scores were introduced into the analysis as covariates to test the extent to which these variables were related to the group differences for the dependent variable. No significant effects were found for this covariate (all  $ps > .18$ ), and so a simpler ANOVA model was tested.

Individuals with ASD were overall slower than individuals in the TD group,  $F(1,32) = 27.09, p = .00001, \eta_p^2 = 0.47$ . The effect of trial-type was reliable,  $F(2,62) = 17.94, p < .00001, \eta_p^2 = 0.37$ , characterized by a reliable linear trend,  $F(1,31) = 33.38, p < .00001, \eta_p^2 = 0.52$ , which indicated that the repeated and variable trials improved RT performance compared to the novel trials. Improved search time in the repeated trials over the novel trials, i.e., ‘contextual cueing’, resulted from specific learning of the repeated trials as well as perceptual/skill learning (Chun & Phelps, 1999; Schneider & Shiffrin, 1977). Improved search time in the repeated trials over the variable ones shows that associative learning produces greater search time benefits compared to familiarity effects.

Participants did not generally become faster over time, as revealed by the lack of a main effect of epoch ( $F < 1$ ), however there was an interaction of trial-type and epoch,  $F(2,62) = 4.30, p < .05, \eta_p^2 = 0.12$ . In order to establish the source of this interaction the data from each trial-type were analyzed separately using a mixed ANOVA with one within-subjects factor (Epoch: 1<sup>st</sup>, 2<sup>nd</sup>) and one between-subjects

factor (Group: ASD, TD). Results revealed that search time became faster for repeated trials,  $F(1,31) = 8.66, p < .01, \eta_p^2 = 0.22$ , but not for variable ( $F < 1$ ) or novel trials,  $F(1,31) = 1.79, p = .19, \eta_p^2 = 0.055$ . There was also an epoch x group interaction in the novel trials,  $F(1,31) = 4.215, p < .05, \eta_p^2 = 0.12$ , and as pair-wise comparisons using the Bonferroni correction showed, this was because the search time in the novel trials increased from epoch 1 to epoch 2 for the TD group ( $p < .05$ ) and not for the ASD group ( $p = .61$ ). This ‘novelty aversion’ that the TD group shows is puzzling and it has also been reported in Brockmole and Henderson’s (2006b) study.

The interaction of group with trial-type was not significant ( $F < 1$ ) which suggests that the magnitude of learning was no different between the two groups. The transformation of the dependent variable into a measure that expresses learning as a proportion of baseline speed (the difference in search time between trial-types/mean search time on novel trials), provided the same of results, thereby reinforcing the conclusion that learning is no different between the two groups.

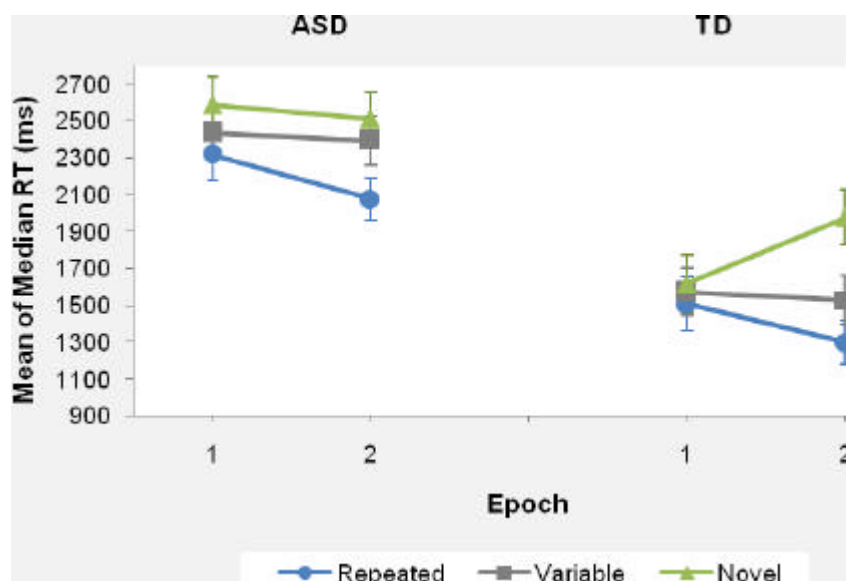


Figure 3.2. Mean of median reaction time (in milliseconds) across the 3 trial-types as a function of epoch (one epoch = 2 blocks) and group, from Experiment 2.

Error bars show the standard error of the mean. The repeated and variable trial-types show additional learning compared to the novel trial-type.

*Recognition Phase.* To establish whether participants had explicit memory of the repeated displays, the remembering of the repeated displays as previously seen must be significantly better than the false remembering of the novel ones as previously seen. Thus, we compared the hit rate (correct recognition of the repeated and variable displays as previously seen) with the false alarm rate (incorrect recognition of the novel displays as previously seen). Nine ASD and 8 TD participants completed the recognition phase of this experiment. A mixed ANOVA with one within-subjects factor (Rate: Hit<sub>Repeated</sub>, Hit<sub>Variable</sub>, False<sub>Novel</sub>) and one between-subjects factor (Group: ASD, TD) revealed that the hit rate for the repeated (ASD = 56%, TD = 53 %) and variable trials (ASD = 51%, TD = 53 %) was

significantly different from the false alarm rate of the novel displays (ASD = 14%, TD = 27 %),  $F(2,30) = 16.85$ ,  $p = .00001$ ,  $\eta^2_p = 0.53$ .

*IQ and learning analysis.* Pearson's correlation coefficients were calculated to assess whether differences in chronological age, nonverbal ability and verbal ability were associated with the magnitude of learning ( $RT\ Novel - RT\ Repeated$ ). Pearson's correlations revealed no reliable associations between learning scores and the above measures even when correlations were performed separately for the ASD (range of Pearson's  $r = -.23$  to  $-.37$ ,  $n = 17$ ,  $ps = .14$ ) and the TD group (range of Pearson's  $r = -.24$  to  $-.38$ ,  $n = 16$ ,  $ps = .15$ ). The negative direction of these correlations is surprising, but not much can be said since these correlations are small and non-significant. To conclude, in accordance to previous research (Jiang et al., 2006) explicit learning was not dependent on IQ or age, although the absence of reliable correlations could also be due to the limited variability in IQ and age scores.

### 3.3.3. Discussion

Experiment 2 has demonstrated preserved explicit learning in individuals with ASD and age- and IQ-matched controls as search time in repeated trials decreased across repetitions, compared to search time in the novel trials. Thus, despite the fact that the search time in the ASD group was overall slower compared to the control group, the present experiment provided no evidence that adolescents and adults with ASD have impaired explicit learning of repeated material or difficulty in creating target-context associations. Explicit memory of the repeated scenes was confirmed in both groups by appropriate recognition assessments. Findings also showed an unexpected increase of search time in the novel condition by the TD group and although this has been noted in similar experiments with real-world scenes (Brockmole & Henderson, 2006b) it is

unclear why the same search cost, that probably reflects novelty aversion, was not shown by the ASD group too.

### 3.4. Experiment 3

Experiment 2 revealed that repeated exposure to real-world *objects* led to a decrease in search time for a consistently located target and also that these object-target associations were explicitly encoded in memory. The aim of Experiment 3 was to assess whether repeated exposure to real-world *scenes* can also result in scene-target associations that are explicitly learned. The stimulus set consisted of illustrations of real-world scenes and the stimuli were developed in such a way that the scene identity was more readily available than the constituent parts. In other words, because the scene identity is recognised more rapidly than the constituent parts, it can guide attention to the target's location faster than the constituent parts. A varied set of different scenes was chosen since attentional guidance based on scene identity is more probable if the scene identity is different in every display, than if a scene identity is similar across displays. For example, it will be faster to locate a target in a set of repeated indoors scenes that are different, than in a set of repeated kitchen scenes that look similar. In the latter case, attention would have to be guided by processing the constituent parts.

#### 3.4.1. Method

##### 3.4.1.1. Stimuli, Design and Procedure

The search displays depicted realistically rendered indoors scenes. Twenty target locations were used and the probability of a target appearing in each location was as closely as possible equiprobable for each condition across the experiment. Each scene included a red outline of the letter 'T' presented in 36-point Arial font which

constituted the target. Similarly to Experiment 2, the target pointed to the left or the right and was always superimposed on one of the objects of the scenes, so that for instance it could not appear on the wall but it could appear on a painting on the wall. Design and procedure are identical to Experiment 2, except that in this experiment instead of 5 blocks, participants were presented with 4 blocks of 24 trials. The reduction of the blocks from 5 to 4 was based on pilot studies which showed very obvious learning effects from block 2. The reduction of the number of blocks by one helped to save time in the development of stimuli and also make the experiment faster for participants.

### 3.4.2. Results

#### 3.4.2.1. Exploratory Data Analysis

Homogeneity of variance was verified using Levene's test (Levene, 1960). Normality of the distribution was checked using Q-Q plots and the Shapiro-Wilk test (Shapiro & Wilk, 1965). Distribution was positively skewed for some variables which is expected with RT data (e.g., Whelan, 2008) and finally, the assumption of sphericity was not violated. As with the above experiment we used the mean of median RT.

#### 3.4.2.2. Data Analysis Procedures

*Accuracy.* Overall, accuracy was high and was not significantly affected by block, group or condition (all  $F_s < 1$ ). Trials were excluded from the analysis if they were given an incorrect response (ASD = 1.0 %, TD = 1.6%) or exceeded 20 seconds (less than 1% for each group).

*Reaction Time.* Figure 3.3 illustrates the mean of median RT as a function of epoch, trial-type and group. In the first block of the experiment there were no differences in search time between the three conditions ( $F < 1$ ) (See Appendix 3.2 for

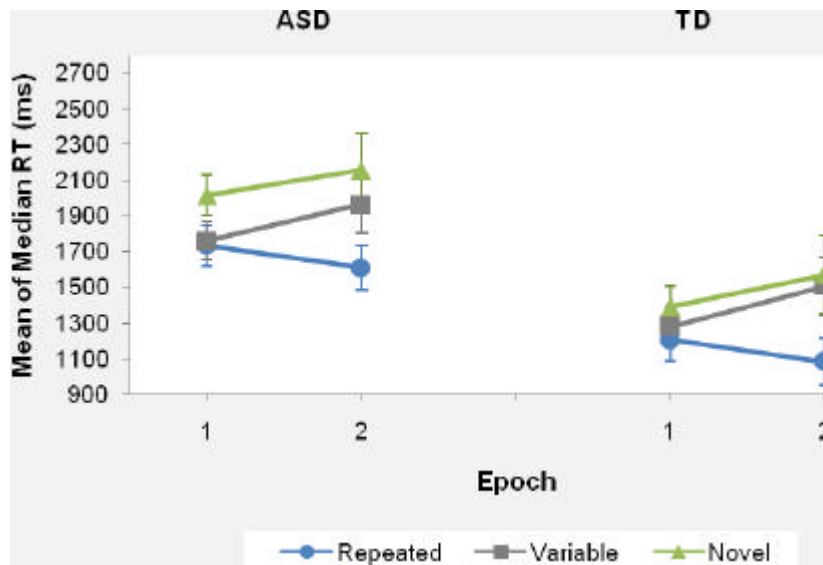


a group by block by trial-type illustration). Mean of median RT was analyzed using a three-factor mixed ANOVA with two within-subjects factors (Epoch: 1<sup>st</sup>, 2<sup>nd</sup>; Trial-Type: Repeated, Variable, Novel) and one between-subjects factor (Group: ASD, TD). As participants had not been well matched, Full Scale IQ scores were introduced into the analysis as covariates to test the extent to which these variables were related to the group differences for the dependent variable. No significant effects were found for this covariate (all  $p > .415$ ), and so a simpler ANOVA model was tested.

Individuals with ASD were overall slower than individuals in the TD group,  $F(1,31) = 9.20, p = .005, \eta_p^2 = 0.23$ . Additionally, the effect of trial-type was reliable,  $F(2,62) = 20.66, p < .00001, \eta_p^2 = 0.40$ , characterized by a reliable linear trend,  $F(1,31) = 30.41, p < .00001, \eta_p^2 = 0.495$ , which replicated the results of the previous experiment, in that the repeated and variable trials improved RT performance compared to the novel trials.

Although, participants did not generally become faster over time, as there was no main effect of epoch,  $F(1,31) = 1.695, p > .05, \eta_p^2 = 0.05$ , there was an interaction of trial-type and epoch,  $F(2,62) = 9.18, p < .001, \eta_p^2 = 0.23$ . In order to establish the source of this interaction the data from each trial-type were analyzed separately using a mixed ANOVA with one within-subjects factor (Epoch: 1<sup>st</sup>, 2<sup>nd</sup>) and one between-subjects factor (Group: ASD, TD). Results revealed that search times became faster for repeated trials,  $F(1,31) = 5.66, p < .05, \eta_p^2 = 0.15$ , increased for variable trials,  $F(1,31) = 7.055, p = .01, \eta_p^2 = 0.185$ , and was not different in the novel trials,  $F(1,31) = 2.49, p = .125, \eta_p^2 = 0.07$ .

Once more, the interaction of group with trial-type was not significant ( $F < 1$ ) which suggests that the magnitude of learning was no different between the two groups and this result was confirmed by the analysis of proportional learning.



*Figure 3.3.* Mean of median reaction time (in milliseconds) across the 3 trial-types as a function of epoch (one epoch = 2 blocks) and group, from Experiment 3. Error bars show the standard error of the mean. The repeated and variable conditions show additional learning compared to the novel condition.

*Recognition Phase.* Eight ASD and 8 TD participants completed the recognition phase of this experiment. In order to establish whether participants had explicit memory of the repeated and variable trials, a mixed ANOVA with one within-subjects factor (Rate: Hit<sub>Repeated</sub>, Hit<sub>Variable</sub>, False<sub>Novel</sub>) and one between-subjects factor (Group: ASD, TD) was performed. Findings revealed that the hit rate for the repeated (ASD = 88%, TD = 69 %) and variable displays (ASD = 69%, TD = 61 %)

was significantly different from the false alarm rate of the novel displays (ASD = 14%, TD = 14 %),  $F(2,28) = 97.87, p < .00001, \eta_p^2 = 0.875$ . The interaction between rate and group was not significant ( $p = 0.17$ ), but there was a main effect of group, as the ASD group showed *greater* recognition memory compared to the control group,  $F(1,14) = 4.48, p = .05, \eta_p^2 = 0.24$ .

*IQ and learning analysis.* Pearson's correlation coefficients were calculated to assess whether differences in chronological age, nonverbal ability and verbal ability were associated with the magnitude of learning ( $RT\ Novel - RT\ Repeated$ ). Pearson's correlations revealed a significant positive association between chronological age and learning in the ASD group ( $r = 0.58, p = 0.01$ ), whereas no other reliable associations between learning scores and the above measures in either the ASD (range of Pearson's  $r = .05$  to  $.20, n = 17, ps = .44$ ) or the comparison group were found (range of Pearson's  $r = -.13$  to  $-.24, n = 16, ps = .37$ ). Thus, once more explicit learning was not found to correlate with IQ, although it did correlate with age in the ASD group only.

### 3.4.3. Discussion

Experiment 3 revealed that there was no evidence of impairments in explicit learning of repeated material or in associating a target with its repeated context in adolescents and adults with ASD, although search times in the ASD group were overall slower compared to the control group. Explicit memory of the repeated scenes was confirmed in both groups by appropriate recognition assessments, but most importantly the ASD group showed greater recognition memory than the TD group. This greater recognition memory may reflect their good abilities in rote memory, but it may have resulted partly from their overall slower search which meant that they searched the displays for longer amounts of time compared to the TD group. However, this latter

explanation could only partly account for the greater recognition rate, since greater recognition was not found in Experiment 2 in which the ASD group was also slower.

Results also showed that search time in the variable condition in which the target changed location, was unexpectedly increased. It is possible that the same search cost was not found in Experiment 2, because as the recognition percentages indicate, recognition rate of the intermediate coherence scenes was lower than that of the high coherence scenes and so target displacement may not have been as salient in the former scenes as it was in the latter. Another possible explanation is that this increase in search time for the variable trials, could reflect the same search cost that occurs when in similar real-world scenes the target changes location and participants look at the original location before they move their eyes to the target's new location (Brockmole & Henderson, 2006a).

### 3.5. Comparison between Experiments

To examine whether the inherent differences between the two experiments influenced performance, we compared RT in the first two blocks (Epoch 1: 1<sup>st</sup> block, 2<sup>nd</sup> block) against RT in the following two blocks (Epoch 2: 3<sup>rd</sup> block and 4<sup>th</sup> block) within the same analysis.

We performed a mixed ANOVA with three within-subjects factors (Epoch: 1<sup>st</sup>, 2<sup>nd</sup>; Experiment: 1<sup>st</sup>, 2<sup>nd</sup>; Trial-Type: Repeated, Variable, Novel) and one between-subjects factor (Group: ASD, TD). As predicted, overall search time was faster in Experiment 3 compared to Experiment 2,  $F(1,31) = 23.44, p < .0001, \eta_p^2 = 0.43$ , supporting the hypothesis that high coherence scenes are associated with faster recognition of the scene identity which guides attention to the target faster than the constituent parts of the intermediate coherence scenes. The main effect of group was

also significant,  $F(1,31) = 21.60, p = .0001, \eta_p^2 = 0.41$ . The interaction of trial-type and experiment was not significant,  $F(2,62) = 1.70, p = .19, \eta_p^2 = 0.05$ , which indicated that learning was equivalent between the two experiments. Finally, there was no interaction between group and experiment,  $F(1,31) = 2.10, p = .16, \eta_p^2 = 0.06$ , suggesting that the ASD group was not any slower in localizing targets embedded in the ‘global context’ of experiment 3 compared to targets embedded in the ‘local parts’ of experiment 2. This finding did not support the hypothesis that the ASD group will perform better in local than global context. All other interaction effects that involved either group or experiment were not significant (all  $ps > .17$ ).

### 3.6. General Discussion

#### 3.6.1. *Summary of Results*

The purpose of the present study was to assess explicit learning of repeated material in adolescents and adults with and without ASD, using the contextual cueing paradigm. The main contributions of the experiments conducted here can be summarized in four points. Firstly, the present study successfully replicated repetition facilitation effects that were at least partly produced by explicit memory (e.g., Brockmole et al., 2006) and showed that individuals with ASD are able to associate a target with its repeated scene context. Secondly, the ASD group was overall slower replicating the finding reported in Chapter 2 and those of other contextual cueing studies (Barnes et al., 2008; Brown et al., in revision). Thirdly, the recognition of the scene identity in high coherence scenes appears to guide attention to the target, faster than the constituent visual features of the intermediate coherence scenes. Finally, associative learning occurring in the repeated trials produces the most substantial improvement in search time, compared to familiarity effects which occur in variable trials and skill learning alone which occurs in novel trials.

### *3.6.2. Relation to Previous Findings*

Faster target detection in repeated trials indicated that there was no evidence of reduced top-down modulation in autism, possibly because learning of the semantic information developed episodically, within the trials, and so there was not much reliance on prior knowledge of how the world is structured which has been shown to be diminished in ASD (Loth et al., 2008). Additionally, this finding of intact explicit learning in ASD corroborated the finding of previous studies that people with ASD can associate an object with a scene, thus suggesting that this processing of contextual information is spared in autism (López & Leekam, 2003).

Preserved explicit memory functioning in ASD corroborates other memory studies in autism which indicate that individuals with high-functioning autism show intact recognition and semantic learning of repeated visual information (e.g., Ben Shalom, 2003; Salmond et al., 2005). The present experiments extend the previous investigations of semantic memory in autism which have administered tasks that tapped more into factual knowledge from long-term stores, since in the present experiments learning was developed through repeated experience with the stimuli, that is in an episodic manner. Furthermore, this is the first study that developed an intermediate version of the contextual cueing task which seems to lie between the standard implicit and explicit versions of the contextual cueing tasks. This new task represents a novel way of assessing how semantic visual features influence memory and learning in the contextual cueing task.

### *3.6.3. Theoretical Implications*

The findings of preserved explicit memory presented here add to the growing evidence (e.g., Mottron, Morasse, & Belleville, 2001; Renner et al., 2000) that autism is not an amnesic disorder characterised by an impaired explicit memory. They also

represent a substantial challenge to proposals of the weak central coherence theory (Frith, 1989) that autism is characterised by a deficit in integrating information in context which leads to an impairment in memorizing information in context. The present thesis showed that context learning, defined as the ability to recognize a repeated context and associate it with its target location, was found to be preserved both when the context was defined as a collection of objects with semantic value (Experiments 2) and as a whole through which a gist could be extracted (Experiment 3).

### 3.6.4. *Critique of Method*

The use of scene stimuli over letter arrays as a method of measuring explicit learning carries both advantages and disadvantages. The benefit from using scene stimuli is that scenes have a realism that stimulus arrays of letters do not (Chun, 2003) which results in attaining greater ecological validity to the real-world behaviour (Hollingworth, 2009). However, a rigorous experimental control of the various stimulus properties such as size and location of objects is difficult with scene stimuli. To this end, the stimuli for the present study were developed using a 3D graphics program rather than real-world photographs as only the former permits all visual features of the stimuli to be manipulated.

Strength of the present study can also be considered the inclusion of another baseline measure, namely the *variable condition*, which none of the published studies on explicit contextual cueing tasks have used. The variable condition is necessary for the attainment of a purer measure of associative learning, because it allows the dissociation between familiarity and associative learning. The improvements in search time occurring because of familiarity with repeated exposure to the same scene context (variable condition) were found to be smaller than those occurring because of

familiarity and associative learning (repeated condition). Thus, the contextual cueing effect cannot be accounted by perceptual familiarity with the scene context alone, but rather reflects an associative learning mechanism that allows the scene context to be associatively learned with the target location.

A limitation of the present study was the lack of complete counterbalancing and as a result there were no different groups of stimuli that presented all possible combinations of the experimental conditions, but instead all participants viewed the exact same stimuli. This may have contributed to the unexpected finding of an increase in search times for the novel condition in the TD group, although it is not clear why the same finding did not characterize performance of the ASD group.

### *3.6.5. Conclusions and Next Steps*

To summarise, although it is difficult to draw strong conclusions from null results, the findings of the present experiments suggest that individuals with ASD in adolescence and adulthood show preserved explicit learning of repeated material and an ability to associate a target with its repeated context. Therefore, the finding of reduced implicit learning in ASD shown in Chapter 2 may not be related to difficulties with creating target-context associations, but related to implicit learning impairments per se.

However, the limitations in the methodology used in Chapter 2, most notably the early differences between the repeated and novel conditions, demand another attempt to investigate implicit learning.



## 4. LOCAL PROCESSING CONTRIBUTIONS TO IMPLICIT LEARNING OF VISUOSPATIAL CONTEXT

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### 4.1. Introduction

The aim of the experiments reported in this chapter was to revisit the use of the contextual cueing paradigm outlined in chapter 2 in order to improve the methodology and address further questions. In the period of developing the research for this thesis, two contextual cueing studies were published in TD individuals (Brady & Chun, 2007; Olson & Chun, 2002), which led to a reformulation of the earlier designed Experiment 1, reported in chapter 2. Both studies introduced a more economical way of producing learning through repeating a part rather than the whole of the display as in the original study (Chun & Jiang, 1998). These studies showed that repeating the few items surrounding the target (local context) yields learning benefits equivalent to repeating all items of the display (global context), confirming that contextual cueing is a local processing task during which observers attend to and learn the local rather than the global context of the repeated trials.

#### *4.1.1. Local Processing in Contextual Cueing*

Barnes et al. (2008) showed intact performance in the contextual cueing task and concluded that this finding not only indicated intact implicit learning, it also indicated intact ability to integrate spatial contextual information. Given that individuals with ASD have long been considered to have difficulty with integrating information and with processing global information (Frith, 1989; Frith & Happé, 1994; Happé & Booth, 2008), such competence in contextual cueing may appear surprising. However, as explained in section 1.3.1, given some other new evidence on the contextual cueing

task, interpretation of global processing in relation to this task may not be as straightforward as it seems.

If contextual cueing is a local processing task, then contrary to Barnes et al.'s (2008) original expectation, one might predict that individuals with ASD could perform even better than controls, given that previous research on visual attention, outlined in the introduction, suggests that individuals with ASD favour the use of a local strategy (e.g., Behrmann et al., 2006; Iarocci et al., 2006; Mottron et al., 2006; Plaisted et al., 1999; Rinehart et al., 2000; Wang et al., 2007). One reason that greater learning in autism was not predicted in Barnes and colleagues' study (2008) may be that the design of their task did not encourage local processing. In Barnes et al.'s study (2008), as well as in Experiment 1 of this thesis, the standard 'global' configuration was repeated on 50% of the trials but was random on the remaining 50% of the trials, and so it did not bias learning to a spatial configuration. Another possibility is that because implicit learning of spatial context matures throughout childhood (Vaidya et al., 2007), the young children that Barnes et al. (2008) examined, may have been less likely to show greater learning.

To fully understand why individuals with ASD may show greater learning of the local context, it must first be noted what it is in the contextual cueing task that drives attention to the local level. Brady and Chun (2007) proposed that local processing can be described in terms of an attentional spotlight that allows observers to use the local repeated context as a cue that will guide their attention to the target area. The allocation of attention to the local area of the target is necessary for encoding the information in the area, because without attention there is no learning (Jiang & Chun, 2001). Hence, it appears that contextual cueing is a local processing task by default, however this feature can be emphasized when only the local part is

repeated because ‘*an optimal (but implicit) strategy would have been to focus only on the local quadrant to minimize distraction and noise*’ (Brady & Chun, 2007, p. 806).

In other words, contextual cueing is a local processing task but depending on the design of the experiment it can become more local or less local.

It is apparent that devising experiments in which different parts of the display repeat would be valuable in exploring which parts are learned better by individuals with ASD. To this end, two main reformulations of Experiment 1 were carried out. Firstly, an experiment was devised in which the local part was consistently repeated and another one in which the non-local part was consistently repeated, thus encouraging a local or a non-local strategy, respectively. Secondly, in order to encourage the use of a certain strategy the procedure of the experiments was altered, in such a way that there was a training phase in which *all* the repeated trials biased attention to a certain level, followed by a transfer phase of repeated and novel trials. The original procedure used by Chun and Jiang (1998), as well as in Barnes et al.’s (2008) study, during which novel and repeated trials were intermixed throughout the experiment, reduces the effect of a bias since only *half* of the trials are the repeated ones.

### 4.1.2. *The Choice of Method*

In the present chapter, learning was biased towards a spatial configuration in two ways. First, in Experiment 4, learning was biased to the *local level* by repeating the local configuration. Local configuration is defined using Brady and Chun’s (2007) terminology, as that part of the configuration that is located immediately adjacent to the target. Second, in Experiment 5 examining the same participants, learning was biased to the non-local level by repeating the non-local configuration. The non-local

level refers to that part of the configuration that does not immediately surround the target, but is spatially distant from it.

To create these different conditions of local and non-local configural context, the entire ‘global’ visual display presented to participants was divided into different sections. In each display, either a local (spatially adjacent) configuration or a non-local (spatially distant) configuration was repeated, while the remaining sections changed randomly across repetitions. Hence, in these partial configurations, only that part of the context which was repeated could be learned, since the remaining parts changed randomly across repetitions. A full configuration was also included, which Chun and Jiang (1998) termed global context, in which the entire display was repeated without changing particular parts of it. Brady and Chun (2007) reported that even in its standard ‘global’ form, the global configuration in the contextual cueing task elicits a ‘local’ strategy, because participants focus their attention to the items in the immediate vicinity to the target. The non-local configurations have been shown in previous research (Brady & Chun, 2007) to influence learning as long as the local configuration is not repeated.

### *4.1.3. Aims and Predictions*

To summarise, it is proposed that individuals with ASD may be good at implicit learning in the contextual cueing task, because this paradigm allows them to use local context that is spatially positioned closely around the target. By biasing implicit learning towards either the local (spatially adjacent) or the non-local (spatially distant) levels of a configuration, it was hypothesised that individuals with ASD will show even greater learning compared to the control group when biased to the local level (Experiment 4: local context), because they habitually focus attention to the local rather than the entire global configuration. However, when a task biases learning

towards the non-local configuration (Experiment 5: non-local context), individuals with ASD will not show greater learning compared to TD individuals.

## 4.2. Method

### 4.2.1. Participants

Sixteen individuals (13 males) with high-functioning autism or Asperger's syndrome aged 16-26 years, were recruited from the same special college for autism. Nine ASD participants had also taken part in Experiments 2 and 3. A comparison group of 17 TD individuals (11 males) aged 17-24 years, was recruited from mainstream further education colleges. All participants obtained FSIQ scores within the average range ( $IQ > 80$ ) and took part in this study as paid volunteers.

The groups were group-wise matched for chronological age,  $t(31) = 0.46$ ,  $p = 0.65$ , verbal IQ,  $t(31) = 0.96$ ,  $p = 0.34$ , non-verbal IQ,  $t(31) = 1.36$ ,  $p = 0.19$  and full-scale IQ,  $t(31) = 1.32$ ,  $p = 0.20$ . Demographic characteristics of the two groups are presented in Table 4.1.

Table 4.1 Participant demographic characteristics (means with S.D.s in brackets)

Group	Age in years	WASI IQ		
		Verbal	Non-verbal	Full-scale
ASD	19 (2.3)	97.8 (14.5)	104.1 (11.2)	101.0 (11.3)
TD	19 (2.1)	102.7 (14.6)	109.4 (11.5)	106.4 (11.9)

### 4.2.2. Apparatus

The stimuli were displayed on a 14-inch Windows Laptop and participants sat approximately 50 cm from the monitor. Participants used a two button response box

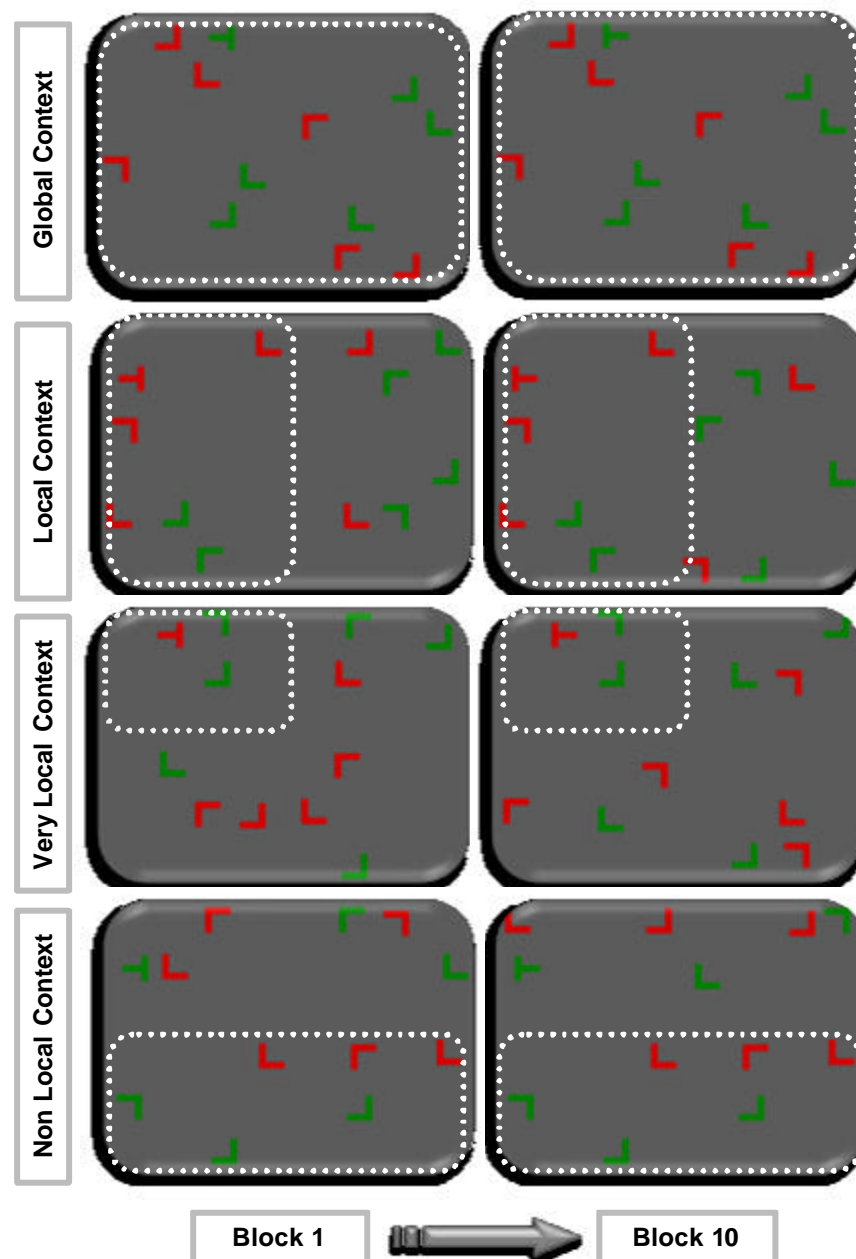
and pressed one of the two buttons corresponding to whether the target T was pointed to the right or to the left.

### 4.2.3. *Stimuli*

The visual search display was the same as in Experiment 1 except that instead of four colours, only two colours were used (red, green), so each display consisted of an equal number of red and green items presented against a grey background. Twenty target locations were chosen in the repeated displays and the same twenty were used in the novel displays. The target locations were counterbalanced across participants creating three different versions of the experiment<sup>3</sup>. Moreover, in each context condition there was an equal number of peripheral and central targets and the colour of the local context (colour of two distractors most adjacent to the target) was either the same or different to the colour of the target on equal number of trials.

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<sup>3</sup> To ensure that these versions did not affect the magnitude of learning we performed a mixed ANOVA for each of the experiments and indeed we did not find main or interaction effects of this factor.



*Figure 4.1.* A schematic depiction of the displays used for the various conditions.

The repeated configuration is shown within the dashed line, which did not appear in the actual experiment, and outside of it the configuration is noisy. The target always appeared in the same location within any particular configuration. In the global context condition (GlobaCxt), the whole display was repeated, but in the other conditions only a section of the display was repeated while the remaining sections changed randomly across repetitions. Also, whereas in the local context (LocalCxt) and very local context (VeryLocalCxt) conditions the target appeared on the same side with the repeated configuration, in the non-local context

condition (NonLocalCxt) the target was placed on the opposite side, amidst the randomly chosen section.

### *4.2.4. Trial Sequence*

Trial sequence was identical to that of Experiment 1.

## *4.3. Experiment 4*

Experiment 4 biased learning to the local level. This bias was accomplished by repeating sections of the configuration which were spatially adjacent to the target. Examples of displays are depicted in Figure 4.1. In the global context condition (GlobalCxt), equivalent to Chun & Jiang's (1998) 'global context' condition, we repeated the entire configuration. In the local context condition (LocalCxt), we repeated half of the display adjacent to the target, while the other half was randomly changed. In the very local context condition (VeryLocalCxt), we repeated the target quadrant, while the rest of the display was randomly changed.

If, as has been claimed, individuals with ASD show local processing bias, it is predicted that they will show equivalent or even greater learning compared to those from the comparison group when biased to process configurations local to the target.

### *4.3.1. Design*

Participants first completed a practice block of 24 trials before completing the three phases in the order shown below. In Chun and Jiang's original 1998 study and in Experiment 1 of the thesis, participants were presented with repeated and novel configurations, randomly intermixed within each block. In contrast, the design of the present experiments is based on more recent contextual cueing studies (Jiang & Leung, 2005; Jiang & Song, 2005; Jiang & Wagner, 2004; Rausei, Makovski, &



Jiang, 2007; Song & Jiang, 2005) in which participants are given a training phase followed by a transfer (test) phase. Pilot studies revealed that this design produces more optimal learning, indicating that in the original design the intermixing of repeated and novel trials interferes with learning of the repeated trials. Pilot studies also showed that the inclusion of two different colours instead of one produces more optimal learning, probably because it makes the display more distinctive.

*Training Phase.* Each training block included 24 different displays which were repeated from block to block for a total of 10 blocks. These 24 displays were made up of 3 context conditions with 8 trials each. The three conditions were: 1. Global context condition (GlobalCxt), created by repeating the whole display from one block to another; 2. Local context condition (LocalCxt), created by repeating only the 5 most adjacent distractors to the target and the rest of the display changed randomly; 3. Very local context condition (VeryLocalCxt), created by repeating only the 2 most adjacent distractors to the target while the rest of the display changed randomly. In all these conditions the target appeared in the same location within any particular configuration.

*Transfer Phase.* In this phase of 4 blocks, half of the displays were the trained-repeated displays and half were novel. In total, there were 96 trials because each of the 24 repeated displays of the training phase (8 GlobalCxt, 8 LocalCxt, 8 VeryLocalCxt) was presented twice and intermixed with these were 48 novel displays. Thus, in each of the four transfer blocks there were randomly intermixed both repeated and novel trials.

*Recognition Phase.* In this final phase observers were presented with 48 displays (24 repeated, 24 novel) and were asked to report whether they thought they

had seen each of these displays before by pressing either a YES or a NO button on the response button box.

### 4.3.2. Results

#### 4.3.2.1. Exploratory Data Analysis

*Assumptions of ANOVA.* Homogeneity of variance was not violated for any of the variables according to Levene's test (Levene, 1960). Normality of distributions was checked using Q-Q plots and the Shapiro-Wilk test (Shapiro & Wilk, 1965).

Distribution was positively skewed for some dependent variables, which is expected with RT data (e.g., Whelan, 2008). For repeated measures analyses, Mauchly's (1940) test was inspected and departure from sphericity was corrected using the Greenhouse-Geisser *epsilon* (Greenhouse & Geisser, 1959). Corrected degrees of freedom are reported to one decimal place.

#### 4.3.2.2. Data Analysis Procedures

Trials were excluded from analysis if a response was not made within 4 seconds or was incorrect. Overall, accuracy was high both in the training and transfer phase (97% and above) and was not significantly affected by block, group, trial-type or condition (all  $p$ s > .13). Figure 4.2 shows mean RT in the training and transfer phases of Experiment 4.

Once more, we averaged the RTs of two blocks into an epoch. In total there were ten training blocks creating 5 training epochs and four transfer blocks creating one transfer epoch of repeated trials and one transfer epoch of novel trials.

*Training.* The mean RT for all correct trials was analyzed using a three-factor mixed ANOVA with two within-subjects factors (Epoch: 1-5; Condition: GlobalCxt,

LocalCxt, VeryLocalCxt) and one between-subjects factor (Group: ASD, TD).

Notably, the main effect of group was not significant,  $F(1,31) = 1.78, p = .19, \eta_p^2 = 0.05$ , as the ASD group did not perform the search task more slowly than the control group. The main effect of epoch was significant,  $F(4,124) = 12.86, p < .00001, \eta_p^2 = 0.29$ , because search times became significantly faster as the experiment progressed due to perceptual/skill learning (Chun & Phelps, 1999; Schneider & Shiffrin, 1977). Also, no other main or interaction effects were found (all  $F_s < 1$ ), except from a marginal main effect of condition,  $F(1.6, 49.1) = 3.05, p = .07, \eta_p^2 = 0.09$ . Single degree of freedom polynomial tests showed a quadratic trend,  $F(1,31) = 10.31, p < .01, \eta_p^2 = 0.250$ , according to which participants tended to respond faster to the global context and very local context conditions compared to the local context condition. ANOVAs calculated separately for each group revealed that the three conditions had equivalent RTs in the first epoch (all  $F_s < 1$ ), suggesting that any differences between conditions later in the experiment, were due to learning of the repeated trials.

*Transfer.* The mean RT for all correct trials was analyzed using a three-factor mixed ANOVA with two within-subjects factors (Trial-Type: Repeated, Novel; Condition: GlobalCxt, LocalCxt, VeryLocalCxt) and one between-subjects factor (Group: ASD, TD). As in previous contextual cueing studies, the main effect of group was significant,  $F(1,31) = 7.725, p < .01, \eta_p^2 = 0.20$ , because the ASD group performed the search task more slowly than the control group. A main effect of trial-type,  $F(1,31) = 37.96, p < .00001, \eta_p^2 = 0.55$ , indicated that both groups detected targets faster in repeated than novel displays, and this benefit in search time shows *contextual cueing*. The main effect of condition was not significant ( $p = 0.3$ ).

Importantly, an interaction effect of trial-type with group was found,  $F(1,31) = 7.11, p = .01, \eta_p^2 = 0.19$ , whereas no other interaction effects were significant (all

$F_s < 1$ ). In order to establish the source of this interaction, two further ANOVAs were conducted on each group's RT data, separately. In the ASD group the mean difference between repeated and novel trials was 127ms ( $SED^4 = 22$ ) and in the TD group it was 50 ms ( $SED = 18$ ). Thus, contextual cueing was greater in the ASD group,  $F(1,15) = 32.86, p < .0001, \eta_p^2 = 0.69$ , compared to the TD group  $F(1,16) = 7.34, p = .015, \eta_p^2 = 0.31$ .

However, it was necessary to find out whether the ASD group was slower compared to the TD group in both the repeated and the novel trials. If the ASD group was slower only in the novel trials, but not in the repeated ones, then it might be argued that greater learning in the ASD group arose from being more adversely affected by novelty. Two further ANOVAs were conducted on each trial-type's RT data, separately. It was found that compared to the TD group, the ASD group searched repeated trials more slowly by 98ms ( $SED = 48$ ),  $F(1,31) = 4.21, p = .05, \eta_p^2 = 0.12$ , and the novel trials more slowly by 175ms ( $SED = 54$ ),  $F(1,31) = 10.37, p < .01, \eta_p^2 = 0.25$ . Thus, the ASD group was slower compared to the TD group, in both types of trials, but more so in the novel trials<sup>5</sup>.

Further analysis, aimed to establish whether the overall slower search time of the ASD group in the *novel* trials may inflate the magnitude of contextual learning (the difference in search time between the two trial types). We took measures of proportional learning for each participant, by dividing the difference in search time between the two trial-types with the mean search time on novel trials. If people with ASD were more adversely affected by novelty, then the greater learning benefit of the

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<sup>4</sup> SED = Standard Error of Difference

<sup>5</sup> In order to explore whether IQ is more related to the slowing in ASD than the TD group, Full Scale IQ was entered as a covariate, but no effects of this covariate were found (all  $p_s > 0.12$ ).

ASD group should disappear when we divided the difference in search time between the two trial-types with search time in the novel trials. Findings showed that the proportional learning was still significantly greater in the ASD than in the TD group,  $F(1,31) = 5.13, p < 0.05$ , and so greater magnitude of learning in the ASD group could not be completely accounted by the overall slower search time in the novel trials. Although, group differences in learning were not an artifact of speed differences because these differences were also observed after equating for response speed, it is difficult to sustain that people with ASD show typical superior learning compared to the TD group, since they did not respond faster to the repeated trials. Thus, it seems that people with ASD show a superior learning which is atypical because it seems to be partly driven by the slower novel trial responding.

*Recognition.* To establish that participants showed implicit memory of the repeated displays, the remembering of the repeated displays as previously seen must not be significantly better than the false remembering of the novel ones as previously seen. Thus, we compared the hit rate (correct recognition of the repeated displays as previously seen) with the false alarm rate (incorrect recognition of the novel displays as previously seen). Chance levels were at 50%. The hit rate was 50% and 43% for the ASD and the TD group respectively. These values were not significantly different from the false alarm rate of 46% and 40% respectively,  $F(1,35) = 2.82, p = .10, \eta^2 = 0.07$ , indicating that the memory representations of context were implicit for both groups.

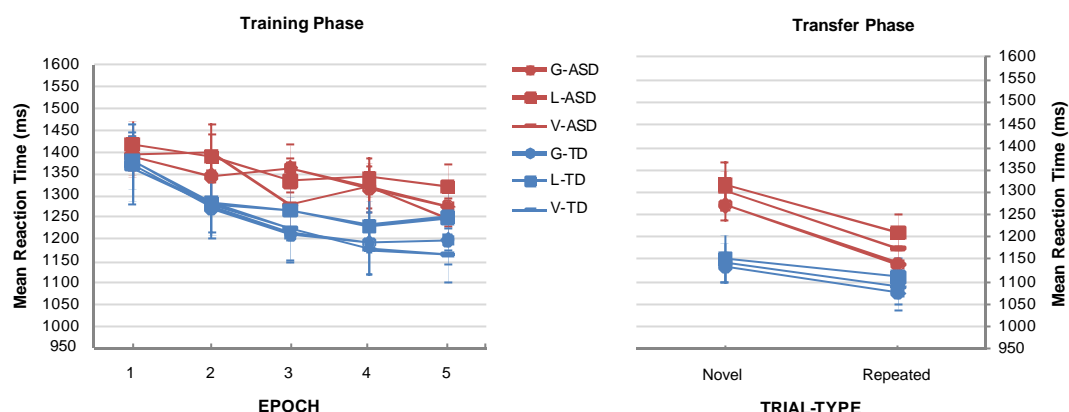


Figure 4.2. Mean response time (in milliseconds) across the global (G), local (L) and very-local (V) context conditions as a function of group and epoch (one epoch = 2 blocks), from Experiment 4.

Error bars show the standard error of the mean. The left panel represents reaction time during the training phase. The right panel represents reaction time in the transfer phase during which both groups show a significantly faster RT for the repeated than the novel trials and the ASD group shows even greater learning compared to the TD group.

*IQ and learning analysis.* Pearson's correlation coefficients were calculated to assess whether differences in chronological age, nonverbal ability and verbal ability were associated with the magnitude of learning ( $RT_{Novel} - RT_{Repeated}$ ). Pearson's correlations revealed no reliable associations between learning scores and the above measures even when correlations were performed separately for the ASD (range of Pearson's  $r = -.01$  to  $-.305$ ,  $n = 16$ ,  $ps = .25$ ) and the TD group (range of Pearson's  $r = .06$  to  $.36$ ,  $n = 17$ ,  $ps = .16$ ).

#### 4.3.3. Discussion

In Experiment 4 local configurations were repeated on 100% of the trials biasing participants to process 'short range', local items. It was expected that participants

could acquire a local configuration more easily, but especially ASD individuals who habitually focus attention to the local parts of a stimulus. Findings revealed that individuals with ASD showed superior implicit learning of local context compared to TD individuals. However, superior learning in ASD was atypical because it appeared to arise partly from diminished search performance in the novel trials rather than faster search time in the repeated trials.

### 4.4. Experiment 5

To extend the validity of the results of Experiment 4, we biased learning to the non-local level (see Figure 4.1). This meant that local processing was more difficult to take place as there was a long distance between the target and the context, whereas at the local level the two are spatially close. If individuals with ASD were only able to implicitly learn from context when they used a local processing strategy, one could predict that they should perform worse than TD individuals. However, according to Mottron et al.'s (2006) model of enhanced perceptual functioning it is predicted that they should show no disadvantage in attending to non-local cues, despite superiority in local processing.

Previous research (Olson & Chun, 2002) has shown that non-local configurations which are located further away from the target can be learned, as long as the local configuration is not repeated and there are no intervening stimuli between the target and its context. In the same study, one aspect of color grouping, in which the target and its context shared the same color, was shown to influence contextual learning to the same extent compared to a condition in which the target and its context did not share the same color. In the present study, another aspect of color grouping was examined, in which the distribution of colors on the display made the display either more or less distinctive. It is known that the more distinctive information

becomes, the more likely it is to be remembered (Craik, 2002). Thus, it was hypothesized that a heterogeneously colored display would render the display more distinctive and it would therefore be remembered and learned more than a homogeneously colored display.

To test these hypotheses three types of conditions were used. In a global context condition (GlobalCxt), the entire configuration was repeated, and therefore the non-local configuration was also repeated. In two non-local conditions, only half of the configuration was repeated and the target was placed on the opposite side amongst the noise, so that there was a long range distance between the target and the repeated configuration. In these two non-local conditions, colour grouping influences on context learning were examined, by manipulating the distribution of the items' color. In the first non-local condition half of the display was comprised of red and the other half of green items (Half-NonLocalCxt), whereas in the second non-local context condition (Random-NonLocalCxt), red and green items were intermixed in random locations on the display. Thus, the random-non local context condition was more heterogeneously colored than the half-non local context condition (see Appendix 4.1 for example stimuli of the non-local conditions).

It was predicted that individuals with ASD will show learning comparable to those of the comparison group. It was also predicted that both groups will show greater learning in the heterogeneously than the homogeneously coloured displays, because they are more distinctive and thus easier to retain them in memory.



#### *4.4.1. Method*

##### *4.4.1.1. Design and Procedure*

The order of presentation of Experiments 4 and 5 was counterbalanced. The design and procedure were identical to Experiment 4, except that in this experiment the local context conditions were substituted with non-local context conditions. The non-local context was created by dividing the display into two sections. Only half of the display was repeated with the target always placed in the opposite ‘noisy’ half. Between the two halves there was a row of no items, because context-target associations cannot be formed when there is noise between them (Olson & Chun, 2002). As the same participants took part in both experiments, new displays for the global context condition were generated.

Thus, there were three conditions: (1) Global context condition (GlobalCxt), similar to the homonymous condition used in Experiment 4, was created by repeating the whole display; (2) Random-non local context condition (Random-NonLocalCxt) was created by repeating half of the display and placing the target in the non-repeated/noisy half; (3) Half-non local context condition (Half-NonLocalCxt) was created in the same way as the random-non local context, but in this condition the target and half of the display (repeated half) shared the same colour, while the other half (noisy half) was of a different colour. For instance, if the target and the repeated half were red, then the noisy half would be green and vice versa. Thus, in this third condition the distribution of the colors on the display made the display less distinctive compared to the random-non local context condition.

#### 4.4.2. Results

##### 4.4.2.1. Exploratory Data Analysis

*Assumptions of ANOVA.* Homogeneity of variance was not violated for any of the variables according to Levene's test (Levene, 1960). Normality of distributions was checked using Q-Q plots and the Shapiro-Wilk test (Shapiro & Wilk, 1965).

Distribution was positively skewed for some dependent variables, which is expected with RT data (e.g., Whelan, 2008). The sphericity assumption was not violated for any of the variables.

##### 4.4.2.2. Data Analysis Procedures

Trials were excluded from analysis if a response was not made within 4 seconds or was incorrect. Overall, accuracy was high both in the training and transfer phase (97% and above) and was not significantly affected by block, group or condition (all  $p$ s  $>.14$ ).

*Training.* The mean RT for all correct trials was analyzed using a three-factor mixed ANOVA with two within-subjects factors (Epoch: 1-5; Condition: GlobalCxt, Half-NonLocalCxt, Random-NonLocalCxt) and one between-subjects factor (Group: ASD, TD). In accord with previous contextual cueing studies, the ASD group was overall slower than the TD group as shown by the marginally significant effect of group,  $F(1,31) = 3.63, p = .07, \eta_p^2 = 0.105$ . A main effect of condition,  $F(2,62) = 4.125, p < .05, \eta_p^2 = 0.12$ , indicated faster search times when the entire context was repeated (global context condition) compared to when a partial context was repeated (non-local context conditions). Search times also became significantly faster over time due to perceptual/skill learning (Chun & Phelps, 1999; Schneider & Shiffrin, 1977) as revealed by a main effect of epoch,  $F(4,124) = 10.39, p < .00001, \eta_p^2 = 0.25$ . None of

the interaction effects was significant (all  $p$ s > .12). ANOVAs calculated separately for each group revealed that the three conditions had equivalent RTs in the first epoch (all  $p$ s > .21), suggesting that any differences between conditions later in the experiment, were due to learning of the repeated trials.

*Transfer.* The mean RT for all correct trials was analyzed using a three-factor mixed ANOVA with two within-subjects factors (Trial-Type: Repeated, Novel; Condition: GlobalCxt, Half-NonLocalCxt, Random-NonLocalCxt) and one between-subjects factor (Group: ASD, TD). As in previous contextual cueing studies, the main effect of group was significant,  $F(1,31) = 4.44, p < .05, \eta_p^2 = 0.125$ , because the ASD group performed the search task more slowly than the control group. A main effect of trial-type,  $F(1,31) = 10.16, p < .01, \eta_p^2 = 0.25$ , indicated that both groups detected

er than a unique contribution of one of them ADDIN EN.CITE  
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 found that compared to the TD group, the ASD group searched repeated trials more  
 slowly by 128ms (SED = 63),  $F(1,31) = 4.155, p = .05, \eta_p^2 = 0.12$ , and the novel  
 trials more slowly by 130ms (SED = 62),  $F(1,31) = 4.43, p < .05, \eta_p^2 = 0.125$ . Thus,  
 once more the ASD group was slower compared to the TD group, in both types of  
 trials.

There was no main effect of condition ( $F < 1$ ) but there was an interaction of trial-type with condition,  $F(2,62) = 3.21, p < .05, \eta_p^2 = 0.09$ . In order to establish the source of this interaction, pair-wise comparisons using Bonferroni adjustment for family-wise errors were performed. We found a significant difference between the RT in the repeated and novel displays (i.e. contextual cueing) for the global context ( $m =$

57 ms,  $p < 0.0001$ ) and random-non local context condition ( $m = 47\text{ms}$ ,  $p < .05$ ), but not for the half- non local context condition ( $m = 3\text{ms}$ ,  $p = .86$ ).

Although the interaction of trial-type with group was not significant ( $F < 1$ ), pair-wise comparisons using Bonferroni adjustment for family-wise errors revealed that while the ASD group showed greater learning in the global context condition ( $m = 72\text{ms}$ ,  $p < 0.001$ ) compared to the random-non local context condition ( $m = 46\text{ms}$ ,  $p = 0.12$ ), the TD group showed comparable magnitude of learning between the two conditions ( $m = 43\text{ms}$ ,  $p = 0.01$ ;  $m = 50\text{ms}$ ,  $p = 0.08$ , respectively). All other interaction effects were not significant (all  $ps > .28$ ).

To determine whether the overall slower reaction time of the ASD group influenced the magnitude of contextual learning (the difference in search time between the two trial types), measures of proportional learning were taken for each participant (the difference in search time between the two trial types divided by the mean search time on novel trials). Results showed that this proportional learning was not different in the two groups ( $F < 1$ ). In other words, the magnitude of contextual learning did not differ for the two groups even when controlling for differences in baseline speed.

*Recognition.* To establish that participants showed implicit memory of the repeated displays, the remembering of the repeated displays as previously seen must not be significantly better than the false remembering of the novel ones as previously seen. Thus, we compared the hit rate (correct recognition of the repeated displays as previously seen) with the false alarm rate (incorrect recognition of the novel displays as previously seen). Chance levels were at 50%. The hit rate was 39% and 40% for the ASD and the TD group respectively. These values were not significantly different

from the false alarm rate of 42% and 35% respectively ( $F < 1$ ), indicating that the memory representations of context were implicit for both groups.

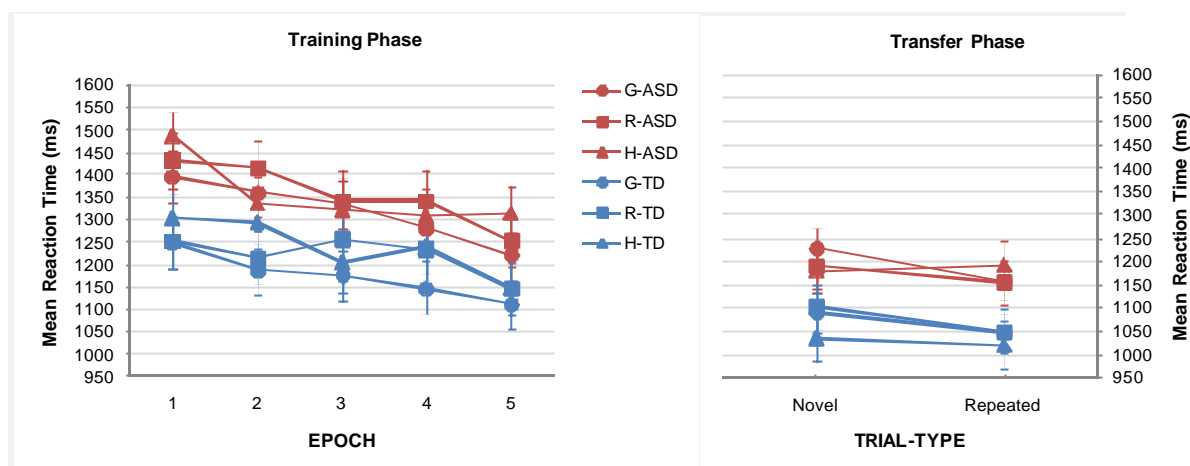


Figure 4.3. Mean response time (in milliseconds) across the global (G), random non-local (R) and half non-local (H) context conditions as a function of group and epoch (one epoch = 2 blocks), from Experiment 5.

Error bars show the standard error of the mean. The left panel represents reaction time during the training phase. The right panel represents reaction time in the transfer phase during which both groups show a significantly faster RT for the repeated than the novel trials.

*IQ and learning analysis.* Pearson's correlation coefficients were calculated to assess whether differences in chronological age, nonverbal ability and verbal ability were associated with the magnitude of learning ( $RT_{Novel} - RT_{Repeated}$ ). Pearson's correlations revealed no reliable associations between learning scores and the above measures even when correlations were performed separately for the ASD (range of Pearson's  $r = -.18$  to  $.23$ ,  $n = 16$ ,  $ps = .40$ ) and the TD group (range of Pearson's  $r = .07$  to  $.32$ ,  $n = 17$ ,  $ps = .21$ ).

#### 4.4.3. Discussion

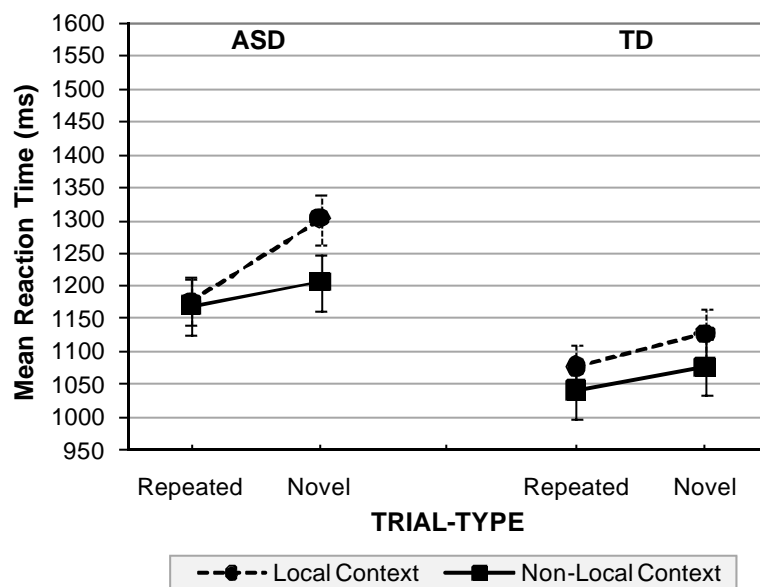
Experiment 5 revealed that in a task that biased learning to the non-local level, individuals with ASD showed implicit learning equivalent to TD individuals. This finding supported the hypothesis that when a non-local strategy is used learning is no different between the groups. However, even in this task, individuals with ASD tended to show greater learning in the condition in which both the local and non-local configuration were repeated (GlobalCxt) than in the non-local context condition (Random-NonLocalCxt), whereas the TD group tended to show comparable learning between the two conditions. Results also supported the hypothesis that for both groups colour facilitated learning when the entire display was more heterogeneously rather than homogeneously colored, possibly because it made it more distinctive. Therefore, it is not only spatial grouping, but also color grouping that affects the magnitude of learning in the contextual cueing task.

#### 4.5. A Comparison of Experiment 4 and 5

Since the same individuals took part in both experiments, it was possible to perform a direct comparison between the two experiments, in order to contrast performance in the local and non-local context learning (see Figure 4.4). A repeated measures ANOVA with one within subjects factor (Proportional learning: Experiment 4 vs Experiment 5) was carried out on the RT data of each group separately. The dependent variable used in this analysis was the proportional learning one, but when the dependent variable represented the difference in RT between the two-trial types which is visually illustrated in Figure 4.4., then the same pattern of results persisted.

Results showed that proportional learning was similar in the two experiments for the TD group ( $F < 1$ ). A main effect of proportional learning was found for the ASD group,  $F(1,15) = 6.20, p < .05, \eta_p^2 = 0.29$ , since individuals with ASD showed

greater learning of the local context (Experiment 4) compared to the non-local context (Experiment 5). However, as Figure 4.4. illustrates, the ASD group shows equivalent search time in the repeated trials across the two experiments, while search time for novel trials is greater in experiment 4 than that in experiment 5. Thus, the superior local learning that the ASD group shows appears to be partly driven by their slower novel trial responding.



*Figure 4.4.* Mean reaction time in the transfer phases of Experiment 4 (Local Context) and Experiment 5 (Non-Local Context).

Error bars show the standard error of the mean. In Experiment 4, the ASD group shows greater reaction time benefit for the repeated over the novel trials, not only when compared to the reaction time benefit of the TD group but also when compared to that of the ASD group in Experiment 5.

## 4.6. General Discussion

### 4.6.1. *Summary of Results*

The present study investigated implicit learning of spatial context in adolescents and adults with high-functioning autism and Asperger's syndrome. Two biases concerning the appearance of the spatial context were contrasted and it was hypothesized that only when a local strategy can be used will learning in ASD be enhanced. Experiment 4 biased learning to the local level by always repeating the local configuration and equivocally supported the hypothesis that attention to the local level enhances learning in ASD, since learning was superior but atypical. On the contrary, when learning was biased to the non-local level by always repeating the non-local configuration (Experiment 5) learning in ASD was equivalent to the TD group. Taken together these results suggest that local processing of context atypically influences implicit learning in the ASD, while non-local learning is typical in ASD.

### 4.6.2. *Interpretation of Atypical Local Learning*

Local learning is superior but atypical in ASD because the two groups differed significantly in novel trials, but only marginally in the repeated trials and so the superior learning of the ASD group appears to arise - at least partly - from slower novel trial responding rather than from faster repeated trial responding. The reason for this novelty aversion is unclear, because no such finding has been reported in typical or clinical populations to which the same task has been employed or in any other implicit learning experiments of the present thesis. Hence, it must be the particular type of this design that caused slower novel trial responding in the ASD group. One speculation is that the introduction of novel trials is particularly surprising or even disruptive when individuals with ASD have adapted to use a strategy that they favour.



Additionally, since learning is measured as the slowing of responses to the novel trials and novel trials are presented towards the end of the experiment, it could be claimed that participants responded more slowly to these because of fatigue and not because they were novel. Firstly, this would have been true if the novel blocks were presented last. However, the transfer phase of the experiment contained 4 blocks of randomly intermixed novel and repeated trials, and not just novel trials. Secondly, a statistical analysis of the two novel blocks of the transfer phase showed, that search time in the second novel block was faster compared to search time in the first novel block, and as Barnes and colleagues (2008) note, faster performance in blocks is inconsistent with fatigued performance.

The claim of a superior learning benefit in ASD may also be difficult to square with the finding that the ASD group is responding overall more slowly than the TD group. In response to this, firstly, it is important to clarify that learning in the ASD group is superior to the TD group, *relative* to their overall reaction time. Secondly, the comparison between the two groups' learning benefit would be troublesome, if overall search levels were somehow correlated with the magnitude of learning. The relationship between the two has been investigated in the contextual cueing literature in regard to whether more attention, in the form of longer search times, leads to greater amounts of learning. Findings showed that the magnitude of search benefit did not depend on the overall search levels (Rausei et al., 2007), in other words spending more time searching and attending did not result in greater learning. Thus, it is unlikely that slower search in ASD would enhance its magnitude of learning. But, even if it did, why was the same benefit not found in Experiment 2 in which responses were also slow? The question of how comparable two groups' learning benefit is

when they differ in overall search performance will need to be investigated in a future study.

### *4.6.3. Relation to Previous Findings*

We successfully replicated previous research in typical (e.g., Brockmole et al., 2006; Chun & Jiang, 1998, 1999; Hodson & Humphreys, 2005; Jiang, Song, & Rigas, 2005; Peterson & Kramer, 2001; Preston & Gabrieli, 2008; Vaidya et al., 2007) and autism populations (Barnes et al., 2008; Brown et al., in revision) showing faster detection of a target in a configuration that is repeated compared to one which is not and also that this kind of learning is supported by implicit memory mechanisms.

There was also an effect of colour grouping on the magnitude of learning. Findings showed that for both groups colour facilitated learning when the global context was heterogeneously rather than homogeneously colored. This aspect of color grouping has not been previously studied in the contextual cueing paradigm and it is possible that the reason why heterogeneity of colors leads to more learning is related to the higher distinctiveness of these displays, which is known to be a factor that facilitates memory (Craik, 2002). The absence of differential effects of colour on group was expected given research that shows intact top-down modulation of colour stimuli (Greenaway & Plaisted, 2005). Although research has also shown atypical color perception in colour discrimination tasks (Franklin, Sowden, Burley, Notman, & Alder, 2008; Heaton, Ludlow, & Roberson, 2008) this could not have affected the present task since target detection was based on orientation rather than colour discrimination.

#### *4.6.4. Theoretical Implications*

The finding of superior learning of the local context cannot be easily interpreted in terms of the theories outlined in the introduction, because of the unexpected slower novel trial responding that produced it. A possible interpretation of the slower responding on novel trials may be related to the common experience that a disruption to a task is more detrimental when we enjoy doing this task than when we do not. It is known that individuals with ASD are good in processing local features (Happé & Frith, 2006; Mottron et al., 2006) which may facilitate successful performance in the task, and so when this process is disrupted by the inclusion of novel trials then search performance becomes significantly slowed. This description is also in accordance with the key clinical feature in autism that an unfamiliar routine may be particularly disruptive. Slower novel trial responding may also result from reduced top-down modulation (Frith, 2003) in as much as it reflects an increased distraction from the novel stimuli that are not relevant.

The intact learning of non-local context, supports the enhanced perceptual functioning model (Mottron et al., 2006) in regards to a preserved ability to allocate attention to local and non-local levels equally well and the evidence of selective tuning of attention in ASD, according to which individuals with ASD are able to allocate attention to local and non-local level depending on the implicit demands of the task (Iarocci et al., 2006). In addition, Iarocci et al. (2006) showed that when both these levels are available in the same task, but the local level is favoured over the non-local, then individuals with ASD show greater sensitivity to the local level. Similarly, in the present study, individuals with ASD showed greater sensitivity to the local level which manifested in terms of an atypical superior learning of local context.

*4.6.5. Conclusions and Next Steps*

In sum, the findings of the present experiments revealed that individuals with ASD, like TD individuals, are able to implicitly learn a spatial context. Therefore, it is unlikely that ASD is characterised by a general deficit in implicit learning (Klinger & Dawson, 2001; Klinger et al., 2007). Local processing featured prominently in these experiments, but the use of reaction time data could not reveal whether indeed attention was focused to the local configuration and whether the two groups differed in the amount of attention that they allocate to it. The aim of the next experiment was to examine eye-movements in order to address these questions.

## 5. IMPLICIT LEARNING OF LOCAL CONTEXT: EVIDENCE FROM EYE MOVEMENTS

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### 5.1. Introduction

The mechanism of associative learning in contextual cueing is not yet well understood. In particular, little is known about the *process* by which learning occurs, that is how targets become associated with the distractor shapes. One possibility is that individual items are associated in pairs through serial processing of the display, but another possibility is that the distractor items are encoded as a set before they can become associated with the target (Chun & Turk-Browne, 2008). However, the *extent* to which learning occurs is better understood. Research has shown that observers encode the information that is local to the target instead of the entire global context (Brady & Chun, 2007). Brady and Chun (2007) claim that the higher sensitivity towards the local context is a result of attention being spatially focused, which suggests that observers pay attention to the local area of the target compared to other parts of the display. In the present study, the aim was to explore how this local processing strategy influences eye movements.

#### 5.1.1. *Context Effects on Eye Movements*

Peterson and Kramer's (2001) study was the first study of eye movements to investigate attention guidance during contextual cueing in letter stimuli. Findings showed that in some trials recognition takes place so rapidly that the first saccade is directed straight to the target, and also that this rapid recognition occurs more frequently in the repeated trials (11.3%) than the novel trials (7.1%). For the remaining 80% of trials, in which recognition was not as rapid, but instead developed later in the search process, results showed that, the initial fixation did not fall closer to

the target in the repeated than the novel trials. However the search benefit for the repeated trials remained, which suggests that in these trials attention was guided specifically to the target, rather than to a generalized target region. Considering these findings together, the authors concluded that although recognition in the contextual cueing task is imperfect, as only in a very small numbers of trials does recognition occur very rapidly, guidance of attention is always accurate since there is search benefit for the repeated over the novel trials.

A study that followed the above by Brockmole and Henderson (2006a) recorded eye movements in a contextual cueing paradigm using real-world scenes, and showed that in this type of stimuli attentional guidance can be highly accurate but also recognition can occur very fast. More specifically, the authors argued that because recognition of repeated trials in scene stimuli occurs very rapidly, eye movements are guided more accurately. For instance, Brockmole and Henderson (2006a) reported that after 10 repetitions, only 1.4 eye movements were needed before the target in the repeated trials was fixated. However, in novel trials the scan pattern ratio, which shows how directly the eyes move to the target, as well as the number of fixations, did not decrease with time. Thus, compared to non-scene stimuli, it appears that fast recognition of the repeated scenes speeds target localization, although there are no search benefits for novel trials.

### *5.1.2. The Choice of Method*

To date, eye movements studies in autism tend to be confined to socially salient stimuli as a means to correlate gaze patterns in these social stimuli with social deficits in the real world (e.g., Klin, Jones, Schultz, & Volkmar, 2003). However, as Boraston and Blakemore (2007) support, it would be beneficial to broaden the scope of stimuli used in eye-tracking studies by employing highly abstract stimuli, such as

the ones used in this chapter, in order to explore whether fixation abnormalities extend to this type of stimuli.

Two recent eye-tracking studies in autism, using highly abstract stimuli in tasks of visual search, have shown faster visual search by individuals with ASD in visual search experiments of abstract stimuli (Joseph et al., 2009; Kemner et al., 2008). Kemner et al. (2008) found that ASD participants made fewer fixations, but the duration of fixations were the same between the two groups. In contrast, Joseph et al. (2009) found that the number of fixations were the same between the groups, but the ASD group made shorter fixations. Both of these findings were attributed to enhanced discrimination abilities in autism, but while Kemner *et al.* pointed to enhanced pre-attentive processing that made targets easier to discriminate, the finding of Joseph *et al.* suggested faster stimulus discriminations at the locus of attention. In the present study, the duration of fixations will be measured in more detail by inspecting each of the three stages of the visual search process: a. initial fixation, b. from initializing second fixation until before the eyes enter the target area and c. from entering the target area to making a response (Hidalgo-Sotelo, Oliva, & Torralba, 2005).

### 5.1.3. Aims and Predictions

Similar to the previous chapter, in the present study, we biased learning towards a spatial configuration that we repeated. Findings of the experiments in Chapter 4 showed that individuals with ASD show atypical superior learning benefits when the local context is repeated possibly because they focus attention to it. In this chapter we aimed to explore whether eye movements in ASD reveal focused attention to the very local context. To this end we put into direct competition two different conditions that were used in the previous chapter. The first one is the *very local context condition*, in which a small section of two items located immediately adjacent to the target was

repeated, while the remaining sections of the display changed randomly across repetitions. In the global context condition, the entire display was repeated and so there were no changing sections. Thus, in both conditions the local configuration is repeated, but whereas in the very local context condition there are changing sections, the global context condition remains unchanged across repetitions. Another aim was to explore why individuals with ASD show slower visual search, as slower search is a reoccurring finding in the work presented in this thesis. By recording eye movements it will be possible to define at which stage of the visual search process is the ASD group slower than the TD group.

The prediction to be tested here is that both groups will use a local strategy by spending proportionally more time fixating the local context than the other parts of the display. Additionally, individuals with ASD, who in contrast to TD individuals show a bias for local rather than global processing, will spend an even greater amount of the trial time in the local context, compared to the TD group and will therefore show superior local learning.

## 5.2. Method

### 5.2.1. *Participants*

Fifteen individuals (12 males) with ASD aged 17-22 years were recruited from the same special college for autism and all had been diagnosed with high-functioning autism/ Asperger's syndrome by experienced clinicians. Six ASD participants had also taken part in Experiments 4 and 5. A comparison group of 18 TD individuals (16 males) aged 18-34 years, was recruited from mainstream further education colleges. All participants obtained FSIQ scores within the average range ( $IQ > 80$ ) (WASI;



Wechsler, 1999), they had normal or corrected-to-normal visual acuity and took part in this study as paid volunteers.

Demographic characteristics of the two groups are presented in Table 5.1. The groups were group-wise matched for chronological age,  $t(31) = 1.35$ ,  $p = 0.19$ , verbal IQ,  $t(31) = 0.16$ ,  $p = 0.87$ , non-verbal IQ  $t(31) = 0.72$ ,  $p = 0.48$ , and full-scale IQ  $t(31) = 0.36$ ,  $p = 0.72$ .

Table 5.1 Participant demographic characteristics (means with S.D.s in brackets)

Group	Age in years	WASI IQ		
		Verbal	Non-verbal	Full-scale
ASD	19 (1.6)	98.3 (15.5)	104.2 (12.9)	101.3 (12.4)
TD	21 (4.1)	97.6 (9.8)	107.1 (10.3)	102.7 (9.5)

### 5.2.2. Apparatus

A computer with a 14-inch color monitor was used to present the stimuli and record participants' responses. Participants responded by pressing one of two keys on the keyboard depending on where the tail of the target 'T' pointed to the left or to the right. They pressed the 'Z' key for a target pointing to the left and the period '.' key for a target pointing to the right. Eye movements were recorded using an Eyelink II eye-tracker (SR Research Ltd.) with 500-Hz sampling rate and 0.01° resolution. The system uses infrared cameras on a headset to transmit information about the participants' head and pupil positions to the eye tracker. Viewing was binocular, but the movements of only one eye were monitored.

## 5.2.3. Stimuli

The stimuli for the two conditions were identical to the ones used in the global and very local context conditions of the previous experiment. Twelve target locations were chosen in the repeated displays and the same twelve were used in the novel displays. The target locations were counterbalanced across participants creating two different versions of the experiment<sup>6</sup>. Examples of displays are depicted in Figure 5.1.

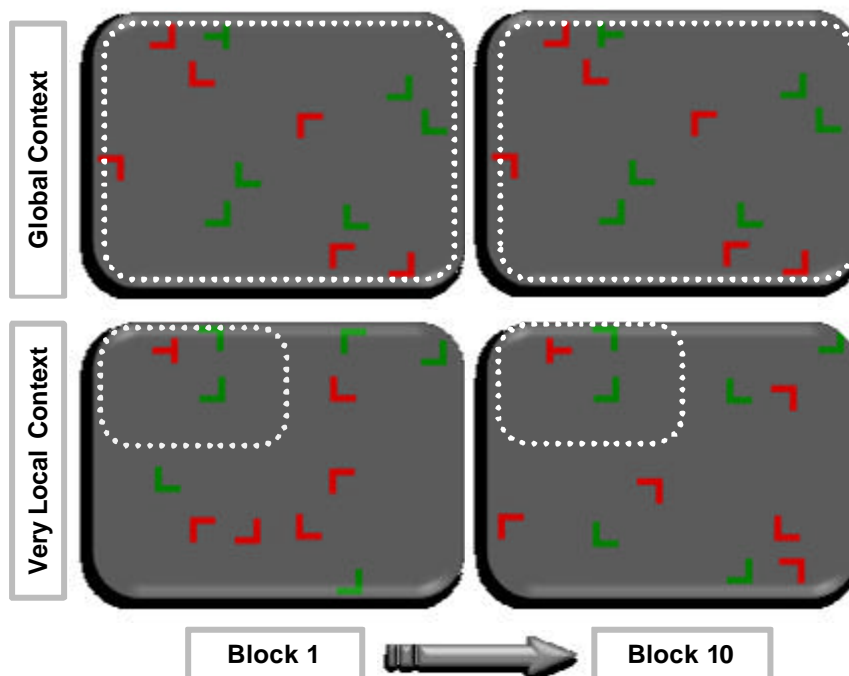


Figure 5.1. Example stimuli of the global context (GlobalCxt) and very local context (VeryLocalCxt) conditions used in Experiment 6.

We repeated the whole display in the global context condition, whereas in the very local context condition we repeated only a quarter (2 items) of the display. The repeated configuration is shown within the dashed line, which did not appear in the actual experiment, and outside of it the configuration is randomly selected.

<sup>6</sup> To ensure that these versions did not affect the magnitude of learning we performed a mixed ANOVA for each of the experiments and there were no main or interaction effects of this factor.

#### 5.2.4. Design and Procedure

Participants first completed a practice block of 24 trials before completing the three phases in the order shown below.

*Training Phase.* Each training block included 16 different displays which were repeated from block to block for a total of 10 blocks. These 16 displays were made up of 2 context conditions with 8 trials each. The two context conditions were: 1. Global context condition (GlobalCxt), created by repeating the whole display from one block to another; 2. Very local context condition (VeryLocalCxt), created by repeating only the 2 most adjacent distractors of the target while the rest of the display changed randomly. In both context conditions the target appeared in the same location within any particular configuration.

*Transfer Phase.* In this phase of 4 blocks, half of the displays were the trained-repeated displays and half were novel. In total, there were 64 trials because each of the 16 repeated displays of the training phase (8 GlobalCxt, 8 VeryLocalCxt) was presented twice and intermixed with these were 32 novel displays.

*Recognition Phase.* In this final phase participants were presented with 32 displays (16 repeated, 16 novel) and were asked to report whether they thought they had seen each of these displays before by pressing either a YES or a NO button on a response button box. Two questions that have recently been added in the recognition phase of contextual cueing studies (Olson & Chun, 2002) were also included here. Firstly, participants were asked to report if they noticed whether certain displays were repeated from block to block and secondly, whether they tried to memorise the patterns in the displays. In both of these questions they also responded by pressing a YES or a NO button on the response button box.

### 5.2.5. Trial Sequence

Participants pressed the spacebar to initiate each block and at the end of each block, they were allowed to take a break. Each visual search trial began with a 500msec fixation period followed by the search display which remained on the screen until the participant made a response. This procedure allowed us to perform a drift correction, and ensured that participants fixated the centre of the screen.

### 5.2.6. Results

#### 5.2.6.1. Exploratory Data Analysis: Manual Responses and Eye movements

Homogeneity of variance was very rarely violated, according to Levene's test (Levene, 1960), but due to fairly balanced sample size this is unlikely to constitute a problem (Cardinal & Aitken, 2006). Normality of distributions was checked using Q-Q plots and the Shapiro-Wilk test (Shapiro & Wilk, 1965). Distribution was mainly normal and positively skewed for only a few dependent variables, which is expected with RT data (e.g., Whelan, 2008). For repeated measures analyses, Mauchly's (1940) test was inspected and departure from sphericity was corrected using either the Greenhouse-Geisser *epsilon* (Greenhouse & Geisser, 1959) when the violation was substantial ( $\epsilon < 0.75$ ) or the Huynh-Feldt *epsilon* (Huynh & Feldt, 1970) when the violation was minimal ( $\epsilon = 0.75$ ) (Cardinal & Aitken, 2006). Corrected degrees of freedom are reported to one decimal place.

Consistent with other studies (e.g., Chun & Jiang, 1998) we averaged the RTs of two blocks into an epoch as a means to increase the statistical power. In total there were ten training blocks creating 5 training epochs and four transfer blocks creating two transfer epochs.

### 5.2.6.2. Data Analysis Procedures: Manual Responses

Overall, accuracy was high (ASD: 98.8%, TD: 99.2%) and was not significantly affected by block, group, condition or trial-type (all  $p$ s = .30).

*Training.* Figure 5.2 illustrates the mean RT as a function of epoch and condition. In the first block of the experiment there were no differences between the two conditions,  $F < 1$ , suggesting that any differences between conditions later in the experiment, were due to learning of the invariant contexts (See Appendix 5.1 for a block by group and condition illustration). The mean RT for all correct trials was analyzed using a three-factor mixed ANOVA with two within-subjects factors (Epoch: 1-5; Condition: GlobalCxt, VeryLocalCxt) and one between-subjects factor (Group: ASD, TD). The main effect of group was significant,  $F(1,31) = 4.46$ ,  $p < .05$ ,  $\eta_p^2 = 0.13$ , as the ASD group performed the search task more slowly than the control group. The main effect of epoch was also significant,  $F(2.8,85.5) = 31.72$ ,  $p < .00001$ ,  $\epsilon = 0.69$ ,  $\eta_p^2 = 0.51$ , because search times became significantly faster as the experiment progressed due to perceptual/skill learning (Chun & Phelps, 1999; Schneider & Shiffrin, 1977).

*Transfer.* The mean RT for all correct trials was analyzed using a three-factor mixed ANOVA with two within-subjects factors (Trial-Type: Repeated, Novel; Condition: GlobalCxt, VeryLocalCxt) and one between-subjects factor (Group: ASD, TD). The main effect of group was only marginally significant,  $F(1,31) = 3.92$ ,  $p = .06$ ,  $\eta_p^2 = 0.11$ , as the ASD group performed the search task slightly more slowly than the control group. A main effect of trial-type,  $F(1,31) = 34.15$ ,  $p < .00001$ ,  $\eta_p^2 = 0.52$ , indicated that both groups detected targets faster in repeated than novel displays, and this benefit in search time shows *contextual cueing*.

Although the overall magnitude of contextual cueing was not greater in one of the groups (Trial-type x Group,  $F < 1$ ), a 3-way interaction of trial-type, condition and group was found,  $F(1,31) = 7.75, p < .01, \eta_p^2 = 0.20$ . In order to establish the source of this interaction, two further ANOVAs were conducted on each condition's RT data, separately. Firstly, in the ANOVA performed on the global context condition, there was a main effect of trial-type,  $F(1,31) = 19.69, p < .001, \eta_p^2 = 0.39$ , but no main effect of group,  $F(1,31) = 2.51, p = .12, \eta_p^2 = 0.075$ . Importantly, there was an interaction of trial-type with group,  $F(1,31) = 5.52, p < .05, \eta_p^2 = 0.15$ , because the difference between trial-types was greater in the TD group ( $m = 158$  ms,  $p < .0001$ ) than the ASD group ( $m = 49$  ms,  $p = .17$ ). Secondly, in the ANOVA performed on the very local context condition, there were main effects of trial-type,  $F(1,31) = 8.19, p < .01, \eta_p^2 = 0.21$ , and group,  $F(1,31) = 4.99, p < 0.05, \eta_p^2 = 0.14$ . Similar to experiment 4, it appears that the ASD was especially slower compared to the TD group in novel trials by on average 200ms, while on repeated trials by on average 100ms. Importantly, there was an interaction of trial-type with group,  $F(1,31) = 4.30, p < .05, \eta_p^2 = 0.12$ , because the difference between trial-types was greater in the ASD group ( $m = 131$  ms,  $p < .01$ ) than the TD group ( $m = 21$  ms,  $p = .56$ ). Taken together, this simple effects analysis revealed that ASD group showed greater contextual cueing in the very local context compared to the global context condition, while the TD group showed the opposite pattern.

In order to determine whether the slower reaction time of the ASD group influenced the magnitude of contextual learning (Novel-Repeated), we took measures of proportional learning for each participant  $[(RT_{\text{Novel}} - RT_{\text{Repeated}}) / RT_{\text{Novel}}]$  and found that this proportional learning was still not different in the two groups,  $F < 1$ . However, when we took measures of proportional learning for each of the conditions,

we found an effect of group in the global context condition,  $F(1,31) = 7.91, p < 0.01$ , and only a very marginal effect of group in the very local context condition,  $F(1,31) = 2.99, p = 0.09$ . These results on proportional learning corroborate the above findings of greater learning benefit for the TD group in the global context and of the ASD group in the very local context condition, although the marginal group effect suggests that the slower novel trial responding may again partly account for the superior learning of the local context in ASD.

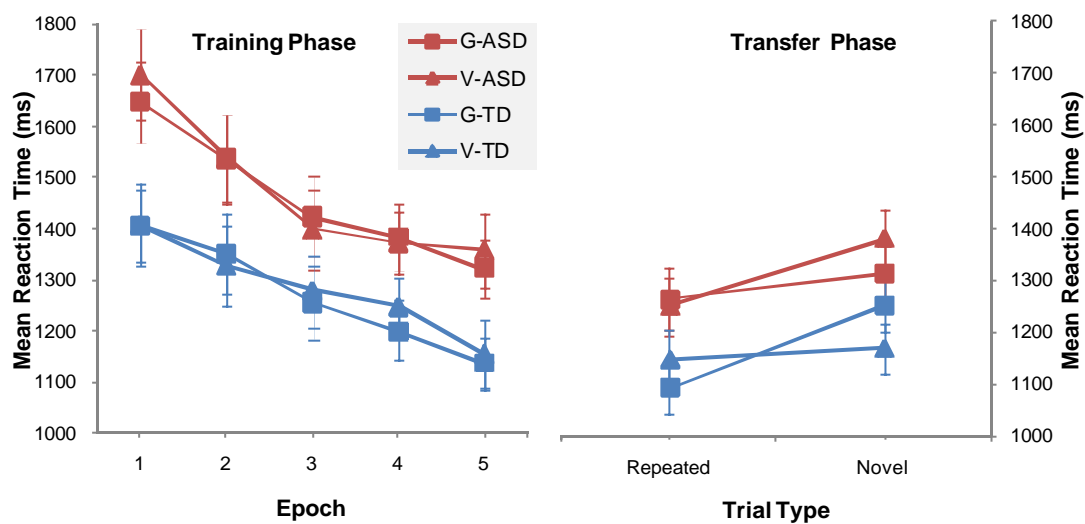


Figure 5.2. Mean reaction time (in milliseconds) across the global context (G) and the very local context (V) conditions as a function of group and epoch (one epoch = 2 blocks).

Error bars show the standard error of the mean. In the transfer phase, the repeated condition shows additional learning compared to the novel condition, and while the ASD shows greater learning in the very local context, the TD group shows greater learning in the global context condition.

*Recognition phase.* Once more we compared hit rate with false alarm rate to establish whether participants had implicit memory of the repeated displays. There was one participant from the ASD group who did not carry out the recognition task, reducing the number of ASD participants to 14. A mixed ANOVA with two within-subjects factors (Rate: Hit, False Alarm; Condition: GlobalCxt, VeryLocalCxt) and one between-subjects factor (Group: ASD, TD) was performed. Findings showed that the main effect of rate was not significant ( $F < 1$ ), as hit rate (TD: 46%, ASD: 53%) did not significantly differ from false alarm rate (TD: 42%, ASD: 62 %). This result indicated that memory representations of context were implicit for both groups.

A small number of participants ( $n_{ASD} = 6$ ,  $n_{TD} = 7$ ) was termed the ‘aware’ group as they responded positively when asked whether they noticed that some displays were repeated, whereas the remaining participants who responded negatively were termed as the ‘unaware’ group ( $n_{ASD} = 8$ ,  $n_{TD} = 11$ ). From this aware group, there were very few participants ( $n_{ASD} = 3$ ,  $n_{TD} = 2$ ) who also reported that they tried to memorize the patterns of the displays. A mixed ANOVA with two within-subjects factors (Rate: Hit, False Alarm; Condition: GlobalCxt, VeryLocalCxt) and two between-subjects factors (Group: ASD, TD; Awareness: Aware, Unaware) was performed.

Results showed a marginally significant interaction of Rate with Awareness,  $F(1,28) = 3.73$ ,  $p = .06$ ,  $\eta_p^2 = 0.12$ . In order to establish the source of this interaction pair-wise comparisons using Bonferroni adjustment for family-wise errors were performed. Results showed that while the aware group showed a significantly higher degree of false alarms than hit rate ( $p = 0.05$ ), the unaware group showed no difference between the two rates ( $p = 0.31$ ). This result indicated that the aware group still



showed implicit memory of context, although it showed a bias toward saying that displays were repeated, even if they were not.

Finally, in order to establish whether the magnitude of contextual cueing was modulated by awareness, another mixed ANOVA with two within-subjects factors (Trial-Type: Repeated, Novel; Condition: GlobalCxt, VeryLocalCxt) and two between-subjects factors (Group: ASD, TD; Awareness: Aware, Unaware) was performed. As awareness did not interact with either trial-type and/or condition (all  $F_s < 1$ ), it can be concluded that awareness did not influence magnitude of learning.

*IQ and learning analysis.* Pearson's correlation coefficients were calculated to assess whether differences in chronological age, nonverbal ability and verbal ability were associated with the magnitude of context learning (*RT Novel-RT Repeated*). Pearson's correlations revealed no reliable associations between learning scores and the above measures ( $ps = .45$ ) even when correlations were performed separately for the ASD (range of Pearson's  $r = -.01$  to  $.17$ ,  $n = 15$ ,  $ps = .54$ ) and the TD group (range of Pearson's  $r = .04$  to  $.15$ ,  $n = 18$ ,  $ps = .54$ ). This suggests that in the present study, as found in all previous studies reported in this thesis, context learning was independent of IQ.

#### 5.2.6.3. Data Analysis Procedures: Eye Movements

A fixation was counted as landing on the target if it fell within a rectangular area of 40 pixels from the centre of the target, termed the target area. Firstly, we explore the number of fixations that occurred before the target was fixated and then the distance between the first fixation and the target. Both of these measures reveal where eye movements occur, but do not reveal the temporal aspect of eye-movements. To explore this aspect, search time for eye movements was decomposed into three

measures: firstly, the duration of the initial fixation; secondly the time interval from movement away from the initial fixation until the first entry to the target area (scan time); and thirdly the time spent from entry in the target area to making a response (gaze duration) (Hidalgo-Sotelo et al., 2005). Finally, to explore whether observers focused their attention to the local area, the proportion of trial time that was spent in the target quadrant was calculated.

*Training phase.* To explore whether the first saccade landed closer to the target in some trials than others, the *distance of the first fixation from the target* was calculated. This distance was smaller in the very local context than in the global context condition,  $F(1,31) = 4.44, p < .05, \eta_p^2 = 0.125$ , indicating that participants were more efficient in locating the target in the very local than the global context condition. However, over time this distance did not change in the same way for both conditions,  $F(1,44) = 3.96, p < .05, \eta_p^2 = 0.11$ . Single degree of freedom polynomial tests revealed that whereas the global context was characterised by a quadratic trend of epoch  $F(1,31) = 12.73, p = .001, \eta_p^2 = 0.29$ , the very local context did not show any reliable effects of epoch (all  $ps > .15$ ). Considered these findings together, although participants' first saccade landed closer to the target in the very local context than the global context, this distance did not decrease over time. Once more, the main effect of group was not significant,  $F < 1$ , suggesting that the distance between the first fixation and the target did not differ between the groups.

The *number of fixations* that occurred before the target was fixated, decreased from 4.7 to 4.0 over the course of 5 epochs,  $F(2,55) = 4.13, p < .05, \eta_p^2 = 0.125$ , which suggests that participants became more efficient over time in locating the target in a display. The two groups did not differ in the overall number of fixations,  $F < 1$ .

The *duration of the initial fixation* tended to increase with time,  $F(2.9, 88.6) = 2.43$ ,  $p = .07$ ,  $\epsilonpsilon = 0.715$ ,  $\eta_p^2 = 0.07$ , and the ASD group showed on average a greater duration of the initial fixation of about 20ms compared to the TD group,  $F(1, 31) = 4.14$ ,  $p = .05$ ,  $\eta_p^2 = 0.12$ . *Scan time* to enter the target region was reduced with time,  $F(4, 120) = 26.40$ ,  $p < .00001$ ,  $\eta_p^2 = 0.47$ , and it was greater in the ASD group than the TD group by an average of about 90 ms,  $F(1, 30) = 5.03$ ,  $p < .05$ ,  $\eta_p^2 = 0.14$ . *Gaze duration* was also reduced with time,  $F(2.3, 66.2) = 4.48$ ,  $p = .01$ ,  $\epsilonpsilon = 0.571$ ,  $\eta_p^2 = 0.13$ , but it was not different in the two groups,  $F < 1$ .

Finally, the *proportion of trial time spent in the target quadrant* was high, but it did not differ between the two groups, as individuals with ASD spent 52% of the trial time in the target quadrant, compared to 55% that the TD individuals spent,  $F(1, 31) = 2.92$ ,  $p = .10$ ,  $\eta_p^2 = 0.86$ . It appears then, that individuals with ASD did not spend more time in the local context than the TD group.

*Transfer phase.* The *distance of the first fixation from the target*, was smaller in the very local context than in the global context condition,  $F(1, 31) = 4.185$ ,  $p < .05$ ,  $\eta_p^2 = 0.12$ . However, there was no main effect of trial-type to indicate that the distance of the first fixation from the target was shorter in the repeated than in the novel trials,  $F(1, 31) = 2.44$ ,  $p = .13$ ,  $\eta_p^2 = 0.07$ . Peterson and Kramer (2001) showed that the distance of the first fixation from the target was shorter for repeated than novel trials, but only when they included trials in which the eyes actually landed on the target in the first fixation (hits). Since, in the present study, there were only very few trials (only three out of the thousands) in which the eyes landed on the target in the first fixation, it is not unexpected that there was no difference between the two trial-types. The percentage of hits in the present study is considerably smaller than the percentages of 11% and 7 % for repeated and novel trials respectively, reported in

Peterson and Kramer's study (2001), but whereas in their study there were 16 blocks, in the present study there only four.

A smaller *number of fixations* were needed to locate the target in the repeated than in the novel trials ( $m = 3.8$  and  $m = 4.2$ , respectively),  $F(1,29) = 13.00$ ,  $p = .001$ ,  $\eta_p^2 = 0.31$ , and once more there was no difference in the overall number of fixations between the two groups,  $F < 1$ .

The *duration of the initial fixation* was not smaller in the repeated than the novel trials,  $F < 1$ , but the ASD group showed on average about 25ms greater duration in the initial fixation than the TD group,  $F(1,31) = 4.90$ ,  $p < .05$ ,  $\eta_p^2 = 0.14$ . *Scan time* to enter the target region was smaller in the repeated than the novel trials,  $F(1,30) = 33.49$ ,  $p < .00001$ ,  $\eta_p^2 = 0.53$  and the amount of scan time did not differ between the two groups,  $F(1,30) = 2.30$ ,  $p = .14$ ,  $\eta_p^2 = 0.07$ . In addition there was an interaction of trial-type, group and condition that

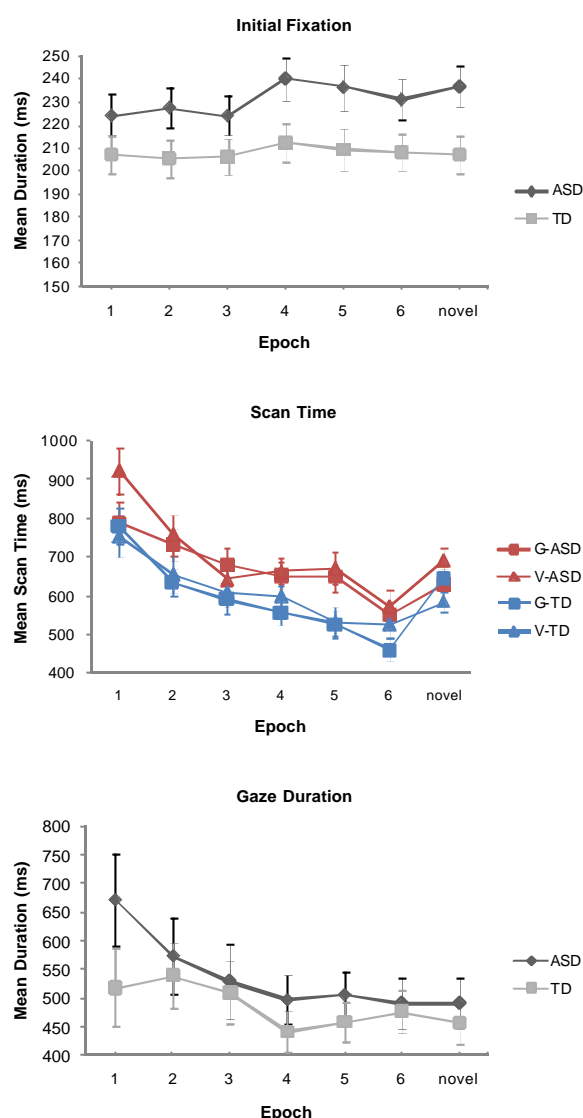


Figure 5.3. Decomposition of reaction time into initial fixation, scan time and gaze duration in the global context (G) and very local context (V).

Error bars show the standard error of the mean.

Epochs 1 to 5 represent the training phase, while the transfer phase is represented in Epoch 6 (repeated trials) and novel epoch (novel trials).

reflects the manual responses' results,  $F(1,30) = 5.05$ ,  $p < .05$ ,  $\eta_p^2 = 0.14$ . In order to establish the source of this interaction pair-wise comparisons using Bonferroni adjustment for family-wise errors were performed. These revealed that whereas the ASD group showed greater difference between the two trial types' scan time in the very local context ( $m = 117$  ms,  $p = .005$ ) compared to the global context condition ( $m = 77$  ms,  $p = .07$ ), the TD group showed the opposite pattern (Global:  $m = 185$  ms,  $p = .00001$ , VeryLocal:  $m = 60$  ms,  $p = .09$ ). Finally, *gaze duration* was not modulated by trial-type, group or condition (all  $F_s < 1$ ).

Once more, the *proportion of trial time spent in the target quadrant* was high, and it differed marginally between the two groups, as individuals with ASD spent less time in the target quadrant (54%) than the TD group (58%),  $F(1,31) = 3.69$ ,  $p = .06$ ,  $\eta_p^2 = 0.11$ . The proportion of trial time spent in the target quadrant tended to be longer in the repeated (57%) than the novel trials (55%),  $F(1,31) = 3.23$ ,  $p = .08$ ,  $\eta_p^2 = 0.09$ , which may suggest that the benefit in search time found in the repeated trials, can result from and/or produce longer dwell time in the local context. This finding was expected, because since contextual cueing helps attention get to the relevant area, it means that less time is spent before the relevant area is reached, and so the proportion of time spent in the relevant area should be greater. The 3-way interaction of group, trial-type and condition was not significant ( $p = 0.29$ ), indicating that contextual cueing in the ASD group was not supported by a local strategy more than for the TD group.

#### 5.2.6.4. Data Analysis Procedures: Summary of Results

Over the course of learning blocks, participants improved their reaction time by showing a gradual decrease in the number of fixations and the scan time needed to localize a target. Slower search in the ASD seemed to derive not from a greater

number of fixations, but from longer durations of fixations. More specifically, the finding that the ASD group was overall slower compared to the TD group was produced from longer durations in the initial fixation and scan time, rather than the time spent from locating a target to responding. Participants were able to locate targets in the repeated trials faster and with a smaller number of fixations than targets in the novel trials, despite the fact that the first saccade did not fall closer to the target in the repeated than the novel trials. Additionally, observers focused more attention to the local area of the target compared to other parts of the display, as they spent approximately 50% of the trial time looking at the target quadrant. Finally, the TD group's learning benefit over the novel trials, was greater in the global context, whereas the ASD group's was in the very local context condition. Thus, eye movements were a useful tool through which we pinpointed the reason for ASD group's slower search and for establishing that both groups appear to use a local strategy by focusing attention to the local context.

### 5.3. General Discussion

#### 5.3.1. *Summary of Results*

The proportionally greater amount of dwell time in the local context confirms the use of a local processing strategy in the contextual cueing task. However, the hypothesis that individuals with ASD would spend an even greater time fixating in the local area than the other parts of the display was not confirmed. Therefore, alternative interpretations in regard to how this local processing strategy may operate in autism are needed. Moreover, learning was superior in the TD group when the global display was repeated and in the ASD group when only a local part was repeated. Results also showed that compared to the TD group, the ASD group spent more time in the initial

fixation and scanning the display, but they were not slower in responding once they detected the target.

### *5.3.2. Relation to Previous Findings*

The finding of greater amount of attention to the local area of the target confirms our hypothesis, but is inconsistent with Peterson and Kramer's (2001) eye-tracking study on the contextual cueing task, which showed that there wasn't any preference for the eyes to go to the general target area. However, maybe the percentages we have reported here are inflated because our proportion measure combines together the scan time in the target area and the time associated with making a response. It would be interesting to find out whether the same benefit persisted by just calculating the proportion of scan time in the target area.

It is also intriguing that although both groups spent more or less the same amount of time in the local context their learning was superior in different conditions. The finding that the ASD group did not spend more time attending to the local area suggests that superior learning of the local context did not emerge from greater amounts of attention in local parts and points to qualitative rather than quantitative group differences in how repeating information is processed. It is possible that the ASD group showed superior learning in the local context for the same reason that was explained in the previous chapter. That is, when people with ASD use a local processing strategy that they favour, the introduction of novel trials is more detrimental to their search performance, leading to slower novel trial responding.

An alternative explanation of why individuals with ASD showed more learning in the very local than the global context condition may pertain to the issue of discriminability. Both conditions had in common that their local configuration was

repeated, and so it is unlikely that the local configuration could explain why performance differed between the two conditions. Instead, to interpret the above finding, it is necessary to understand how these two context conditions differed. While in the very local context condition there are unique/novel parts, which are parts that change across repetitions, in the global context condition all items are common across repetitions. One possible explanation for why conditions influenced differentially the ASD group is related to the popular view that individuals with ASD have enhanced discrimination abilities (Mottron et al., 2006; O'Riordan & Plaisted, 2001; Plaisted et al., 1998a). For instance, in a perceptual learning task, the ASD group discriminated between novel stimuli much better than they discriminated between repeated (common) stimuli (Plaisted et al., 1998a), whereas the control group showed the opposite pattern. The authors concluded that unique stimuli are processed well and common stimuli are processed poorly in autism. It is possible then, that individuals with ASD found it easier to learn from stimuli that contained unique/novel parts (very local context) across repetitions, than from stimuli which contained only common parts (global context).

An even more elegant explanation for the diminished contextual cueing effect that the ASD group shows in the global context compared to the local context is that people with ASD may actually try to learn more than the local context when the global configuration is repeated<sup>7</sup>. In other words, in the global context condition in which more than the local contingencies can be learned, people with ASD may try to encode these contingencies. The diminished learning of the global context compared to the local context may pertain to the added difficulty to learn more contingencies

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<sup>7</sup> I thank Glyn Humphreys (Birmingham University) for this suggestion.



rather than the few of the local context, especially for ASD individuals whose local processing superiority may interfere with such learning. Instead, TD people who by default tend to process information globally may benefit from conditions in which more than a restricted local context is repeated. Thus, the two groups seem to learn according to their rewarded perceptual styles of processing information.

Moreover, the superior learning of the TD group in the global context condition compared to the local context condition is inconsistent with the findings of Brady and Chun (2007) which showed that global predictive displays did not yield greater learning benefits than target-quadrant (local) predictive displays. However, Brady and Chun's (2007) study had double the amount of trials compared to the present experiment, and so one way to explain greater learning in the global predictive trials here is that the visual system may benefit from more items being repeated when there are fewer trials. Especially TD individuals, who tend to process information more globally before they focus attention to local features (Navon, 1977) may benefit even more so than ASD individuals who are known to be free from the same obligation for global processing (Iarocci et al., 2006).

Finally, eye movements' results in the current study revealed that individuals with ASD are slower compared to the TD group, not because they make more fixations, but because the duration of their fixations is longer. One reason why the durations are longer may be related to their difficulties to disengage from one stimulus to the other (Landry & Bryson, 2004; but see, Leekam, López, & Moore, 2000). This interpretation appears even more convincing, when one considers that durations are longer in the period before the target is fixated, but once the eyes enter the target area, the durations in the ASD group are not longer, possibly because individuals with ASD do not need to disengage from anything.

### 5.3.3. *Conclusions and Next Steps*

The results of the present study indicate that both groups use a local strategy in the contextual cueing task, as they spend proportionally more time fixating in the local area of the target, than other parts of the display. This pattern was established for both groups and so, contrary to the initial prediction, it does not appear to be a signature of the autism group. Thus, both groups paid equal amount of attention to the repeated local area, but the TD group showed greater global learning while the ASD group showed greater local learning. Finally, eye movements seem to differ in the two groups, in that during the period before the eyes enter the target area, the ASD group spends more time fixating on the display and this finding could reflect difficulties in their disengagement of attention.

## 6. GENERAL DISCUSSION

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### 6.1. Development of Thesis

Learning is critical for the development of language, social and motor skills, however little is known about whether this process may be disrupted in individuals with ASD as well as how it manifests during their adolescence and adulthood. The aim of the thesis was to increase further our understanding of implicit learning of spatial context in individuals with ASD. The contribution of this thesis is that it integrates an ongoing question in the autism literature, i.e., local processing advantages, with a relatively novel area of investigation, i.e., learning and memory in autism.

The present work on implicit learning of spatial context in autism began in 2004 and was inspired by the weak central coherence theory's proposal of impaired processing of context in autism. The contextual cueing task seemed an appropriate task for measuring how people with autism process implicitly a visual context that was highly abstract and this could also be developed to add to the existing work on processing of visual context using stimuli that were semantic and processes that were explicit. In the years that followed, ideas about both weak central coherence and contextual cueing changed in an important and very similar way. On the one hand, the weak central coherence became less focused on context processing being a deficit and more focused on local processing being a cognitive style. On the other hand the contextual cueing task became more known as a local processing rather than as a global processing task. These new developments led to the understanding that contextual cueing would be an appropriate task for investigating the accumulating evidence of local-global processing abnormalities in autism which prior to this had been primarily studied using Navon-type stimuli. The experiments in this thesis have

been reported in the order that they were chronologically conducted and reflect the shift of focus from global and context processing (Experiments 1-3) to local processing (Experiments 4-6). The average response times and standard errors across Experiments 1 to 3 and Experiments 4 to 6 can be found in Appendix 6.1 and 6.2 respectively.

### 6.2. Summary of Results

#### *6.2.1. Is Implicit Learning Impaired in Autism? Evidence from Chapter 2*

Experiment 1 employed the contextual cueing paradigm in its original form in individuals with and without ASD. Although the two groups were well matched in terms of chronological age and IQ the findings showed that during the first half of the experiment individuals with ASD detected targets in repeated trials more easily than those in the novel trials. However, this was true even in the very first block, which is unexpected because both types of trials should be of equal difficulty, as in this block participants encounter the displays for the very first time. The location of the targets in both sets of trials was matched and therefore it must have been the arrangement of colours and locations of the distractor items that was such that it made some of the targets in the novel trials more salient. It is also unclear, why individuals with ASD did not show the same reaction time benefit in the second half of the experiment. In sum, it was not possible to answer whether implicit learning was impaired in individuals with ASD based on the findings of this experiment, but its contribution was to highlight that the application of an improved counterbalancing is needed.

#### *6.2.2. Intact Explicit Learning in Autism: Evidence from Chapter 3*

In this chapter the contextual cueing paradigm was employed using realistic scene stimuli as the learning context. Repeated search through a particular scene exemplar

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led to faster detection of a target embedded in it and although some implicit learning may have occurred, the most parsimonious account of the type of learning that takes place in these scenes is that it is explicit (Hollingworth, 2009). In addition, memory was explicit as repeated scenes yielded better recognition compared to scenes viewed only once. In other words, the explicit memory of the scene context and layout guided attention to the areas where the target was more likely to be found.

Individuals with ASD were shown to be as able as the comparison group to use memory of previously seen displays in order to guide their attention towards the target location. Thus, it appears that individuals with ASD show preserved explicit memory of repeated material and are also able to memorize contextual information. However, search time was consistently slower in both experiments of explicit learning. The reasons for slower search time may be similar to the ones pertaining to abstract stimuli, which have been outlined in the discussion of chapter 4, but could additionally be related to the greater stimulus complexity that scene stimuli have, since search in the scene stimuli was even slower compared to search in non-scene stimuli. The present finding of faster search time in the ‘full coherence’ scenes compared to the ‘intermediate coherence’, suggests that context guides attention more quickly in the former type of scenes in which recognition is faster. Recognition is faster in the high coherence scenes possibly because the visual system can exploit contextual associations more easily compared to the ‘cabinet of objects’ scenes in which contextual associations between the objects may not be as readily available. These findings are important because they contribute to answering the question of how fast context can affect the allocation of attention which is a matter of great debate (Oliva & Torralba, 2007).

### *6.2.3. Superior Learning or Novelty Aversion? Evidence from Chapter 4*

In this chapter the aim was to study implicit learning of spatial context in ASD by adapting the contextual cueing tasks in order to specify whether the repetition of local or non-local elements is more easily acquired. Two experiments were reported, one in which the local context was predictive of target location and one in which the non-local context was predictive of target location. Findings revealed that individuals with ASD showed greater learning compared to TD individuals when local context was predictive of target location, while ASD and TD individuals did not differ when non-local context was predictive of target location. However, due to a significantly slower novel trial responding in the ASD group, it was difficult to sustain that local processing, in the form of attention to local cues, facilitated performance in the ASD group more than it did for the comparison group. It was concluded that slower novel trial responding rather than a faster search in repeated trials drove part of the effect of superior contextual cueing in ASD and that this slower novel trial responding may reflect a form of novelty aversion.

### *6.2.4. Superior Implicit Learning of Local Context in Autism: Evidence from Chapter 5*

Chapter 5 reported a study that monitored participants' eye movements during visual search when the repeated configuration was made up of the whole display or only a part that was local to the target. Both of these conditions are similar in that the local parts are always repeated and so to find out whether indeed more attention is allocated to the local parts, it was necessary to obtain eye-movements data. Analysis of eye movements supported the claim that contextual cueing is a local processing task, since proportionally more attention was allocated to the local parts of the configuration. It was also found that the ASD group did not show more attention to the local parts than

the TD group, which suggests that local processing in the contextual cueing task is not quantitatively different in the two groups.

It is possible that although both groups allocated the same amounts of attention to the local context, people with autism were able to show greater learning in the local context condition because in this condition there are unique parts, which are parts that change across repetitions, while in the global context condition all items are common across repetitions. The hypothesis of reduced generalization (Plaisted, 2000, 2001) predicts that people with ASD are better able to process novel rather than common stimuli and therefore in accordance to this people with ASD would do better in the local rather than the global condition. However, an even more convincing interpretation is that the two groups learn according to their rewarded perceptual style. Thus, while TD individuals learn more from a global configuration the ASD group learns more from a local configuration. The finding that learning in the global configuration is no greater than in the local condition for the ASD group, may reflect their difficulties in global processing that arise from superior local processing (Happé & Frith, 2006).

To study *where* eye-movements occurred we measured the number of fixations as well as the distance of first fixation from the target and to study the *temporal* allocation of eye-movements we took measures of the duration of the initial fixation, the scan time and the duration of fixations to the target (gaze duration). Findings showed that while the two groups did not differ in terms of where eye-movements occurred they did differ in terms of the temporal aspect of eye-movements. The ASD group showed longer durations in the first fixation and during scanning of the display, but not when fixating the target. This finding, pointed to

possible difficulties in the disengagement of attention during the time before the target is fixated.

### 6.3. Contributions to Theories of Implicit Learning in Autism

Contrary to the prediction of the ‘learning compensation’ hypothesis (Klinger et al., 2007), implicit learning of spatial context seems overall intact and even superior under conditions that promote autistic people’s special skills which implies that there is not a general deficit in implicit learning. Furthermore, this good performance was not a consequence of compensation by IQ, although we did not examine whether it may be a consequence of compensation by explicit learning. The findings of this thesis as well as those of others do not seem to support the idea of a deficit in implicit learning in autism, but further work is needed to evaluate the relationship between implicit and explicit learning as well as implicit learning and autism symptomatology. The proposal by Mostofsky and colleagues of impaired implicit learning when motor skills are involved, is difficult to evaluate using the contextual cueing task, since this task is not an implicit *motor* learning task, but an implicit *visual* learning one (van Asselen et al., 2009).

Recently, Mottron and colleagues (2009, p. 1386) proposed that pattern detection mechanisms may be “*enhanced*” and “*especially active in autism*” and can lead to both savant abilities and the exceptional abilities found in non-savants. Also, in an attempt to explain why pattern detection may be enhanced, Mottron and colleagues (2009, p. 1389) claim that “*Overexposure to material highly loaded with internal structure plausibly favours implicit learning and storage of information units based on their perceptual similarity, and more generally, of expertise effects.*” The



present experiments which investigated implicit learning of patterns can inform this proposition which has not yet been tested empirically. It appears that detection of patterns may need to be combined with other abilities, such as local processing, in order to result in enhanced performance<sup>8</sup>. Thus, in Chapter 5 for instance, enhanced learning was confined to a condition in which the recurring pattern constituted a part local to the target rather than a global configuration.

### 6.4. Contributions to Cognitive Theories of Autism

In this section, the aim is to discuss how the main findings presented in this thesis could inform current cognitive theories of autism. These main findings can be summarized as: 1.) overall slower visual search, 2.) intact explicit learning and 3.) intact or superior implicit learning of context.

#### 6.4.1. *Slower Visual Search*

Superior visual search in autism has been linked to an enhanced ability to discriminate the target from its distractors (O'Riordan & Plaisted, 2001) and recent research has corroborated this by suggesting that superior visual search in autism stems from enhanced perception of features rather than from atypicalities in attentional mechanisms per se (Joseph et al., 2009). The lack of superior visual search in autism across the six experiments of the present thesis reduces the universality of this trait to ASD and the probability of the enhanced discrimination hypothesis as a likely explanation of the ASD performance in the contextual cueing task. It is possible that not all visual search tasks are sensitive enough to capture the superiorities in autism, or as pointed out elsewhere (Joseph et al., 2009), superior visual search may be restricted to moderately difficult search tasks or tasks in which pre-attentive

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<sup>8</sup> I thank Laurent Mottron (University of Montréal) for this suggestion.

processing can occur. Additionally, superior search may not constitute a universal trait in autism, but may only be found in a subgroup of individuals, and already some research has linked superior visual search only to those individuals with visuospatial peaks in a modified version of the block design test (Caron et al., 2006). Thus, enhanced discrimination, although it explains in a very refined way some of the superior abilities in autism, its scope to a range of tasks and universality as well as specificity to the autism population remains unknown. Currently, Mottron et al. (2006) argue that enhanced discrimination is just one of the many instances of enhanced perceptual processing in autism rather than a theoretical framework that can explain a wider range of cognitive phenomena in autism.

### *6.4.2. Intact Learning of Scene Context*

In respect of the experiments employing semantic, high-level stimuli, the prediction was that the influence of repeated exposure to the same visuospatial information on target detection (top-down modulation) would be reduced (Happé & Frith, 2006). If reduced then this would suggest that people with ASD would not benefit from prior experience and therefore show reduced learning compared to the control group. Another prediction pertained to the optional nature of top-down modulation in autism (Mottron et al., 2006), according to which people with ASD present with a response variability which arises from a greater autonomy of low-level operations from higher-order interventions. This optional nature of top-down modulation in autism, would predict that whether ASD individuals use prior experience, would depend on task demands rather than on a default setting as it is the case with TD individuals (Mottron et al., 2007). Findings showed that scene learning was equivalent between the two groups and therefore top-down modulation in the contextual cueing task appears intact in ASD.

These findings help to set the boundaries of the reduced top-down modulation hypothesis in autism (Happé & Frith, 2006). According to this hypothesis, people with ASD are unable to use previously acquired and stored knowledge such as schemas or expectations of how the world is structured, but in the experiments presented here, when prior experience is created in an episodic manner, that is within the trials, then they are able to use this knowledge in order to help them guide their attention to the target. This intact performance may be possible only when the knowledge required rests on the ability to recognize previously viewed scenes, rather than on the ability to recall how the world is structured. Therefore, top-down modulation may be intact under conditions of episodic experience with semantic material, but diminished under conditions in which stored knowledge must be retrieved from long-term memory rather than in an episodic manner (Loth et al., 2008). This proposal seems to be getting close to the point about whether implicit learning is occurring in the scenes as well as explicit, because episodic memory is by definition explicit, but retrieval from long-term memory may not lead to conscious recognition and so can be implicit. In other words, top-down modulation may be reduced under conditions that require implicit rather than explicit memory contributions.

The evidence for the optional nature of top-down modulation (Mottron et al., 2006) derives from tasks that employ low-level stimuli to examine the influence of episodic prior-knowledge on perceptual categorization (e.g., Soulières et al., 2007) and shape reproduction (Ropar & Mitchell, 2002). In both types of study, knowledge is created within the trials in an episodic manner, whereas there is very limited semantic knowledge involved since the stimuli are simple shapes. In the present experiments prior-knowledge is also created episodically, but there is a greater degree

of explicit knowledge involved compared to the low-level stimuli used above, because the stimuli used are more semantic. It is possible then that tasks which employ low-level stimuli and which do not involve semantic knowledge, may be more appropriate to unfold the optional nature of top-down modulation, because these tasks encourage the discovery of what strategy may be advantageous, while in tasks of explicit learning one does not need to discover the strategy, but spontaneously adopts the strategy of using the semantic knowledge which is readily available. Once more, implicit memory may be more in play in those studies that use low-level stimuli and so this may contribute to the lack of top-down modulation.

### *6.4.3. Intact or Superior Implicit Learning of Context*

With regard to the experiments employing non-semantic stimuli, it is local rather than global coherence which underlies improved performance in the contextual cueing task because local learning drives most of the contextual cueing effect. Thus, both the superior local processing and the intact local coherence were expected to facilitate implicit learning of local context in ASD. Although it is not yet clear whether local or global processing abilities underlie successful performance in the non-local learning conditions, their ability to allocate attention according to the implicit demands of the task was expected to yield intact learning of non-local context in ASD.

The hypothesis of intact local coherence supports that in autism there is an intact ability to connect neighboring items and the hypothesis of intact global processing assumes preserved ability of attention to global cues. These hypotheses were confirmed in Experiments 4 and 5 which showed intact implicit learning in ASD of local and non-local context, respectively. The hypothesis of a bias towards local processing (Happé & Frith, 2006) and its ‘locally oriented attention’ counterpart (Mottron et al., 2006) in autism are thought to manifest in a tendency towards

attention to local parts of the configuration. Attention to local parts may have led to the superior implicit learning of local context in ASD, while reduced learning in the global context points to global processing atypicalities in ASD (Experiment 6).

Therefore, the present thesis supports the recent reformulation of the weak central coherence theory, according to which local processing preferences in autism may not be accompanied by integration deficits, when integration involves connecting local/adjacent items, but when global coherence is required individuals with ASD are less able to perform as well as TD individuals (Happé & Booth, 2008; Happé & Frith, 2006).

### 6.5. Limitations of Thesis

Some of the limitations pertaining to the generalization of the results need to be noted. The diagnostic scores from measures such as ADI/ADOS were not available which weakened the comparison of the present study with other implicit learning studies in autism. So it was not possible to correlate clinical characteristics with performance in the contextual cueing task. This may be an important direction for future research, particularly in light of recent studies which show that individuals with language delay have perceptual peaks (Bonnell et al., submitted; Jones et al., 2009)<sup>9</sup>. For instance, is it possible that individuals with language delay also show greater perceptual learning than those who do not? Additionally, the lack of diagnostic information prevented the investigation of subtype effects in the present study, which is important especially as high-functioning autism and Asperger's syndrome may reflect distinct disorders (e.g., Leekam, 2007; Sahyoun, Soulières, Belliveau, Mottron, & Mody, 2009). For instance, Sahyoun and colleagues (2009) support the proposal that while people with high-

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<sup>9</sup> I thank Laurent Mottron (University of Montréal) for pointing this out.

functioning autism may rely more on visuospatial strategies rather than conceptual-based strategies, people with Asperger's syndrome show equivalent use of two strategies.

Also, the participation of individuals with high-functioning autism and Asperger's syndrome reduces the population validity of the present thesis as we do not know whether the present results generalise to individuals with lower intellectual function. Although, it is often challenging to devise tasks that are suitable for individuals who are less able, the present task seems suitable for these individuals as the task demands are low, learning is unintentional and it does not depend on executive function (Barnes, 2009), although Gordon and Stark (2007) propose that additional exposure to the repeated information may be required. Research examining less able individuals, would be particularly timely not only because it is the less able individuals who have greater training needs, but also because it will increase our understanding of how implicit learning is manifested in individuals with below average intellectual function. Also, the findings of the thesis are constrained by the ages of the samples examined, which ranged from late adolescence to early adulthood, but a developmental approach is timely, especially because the different studies of implicit learning in autism are examining different ages and their differing results may be accounted for developmental factors.

### 6.6. Follow-up Experiments

Some of the experiments in this thesis suggest that implicit learning of local context in autism is superior compared to that of TD individuals. This interpretation of superior learning may be difficult to square with the overall slower search in ASD, mostly because it is not known how slowing of responses may influence the magnitude of learning. However, this is most probably not a straightforward relationship because

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the ASD group which is slower across experiments only shows atypical and/or superior learning in the local context conditions. A type of task that assesses local and global processing abilities while the ASD group often shows faster search times constitutes the Navon task. A recent study has adapted an implicit learning task that measures artificial grammar learning using strings of Navon-type letters (Tanaka, Kiyokawa, Yamada, Dienes, & Shigemasa, 2008). This novel task applied in autism would constitute an ideal way of assessing how local vs global processing abilities may influence implicit learning in autism.

According to a revisiting of the weak central coherence theory (Happé & Booth, 2008, p. 60), the authors propose that ‘*Tasks need to be devised that can test integrative failure independently of superior local processing*’, thus calling for new measures of weak coherence. In the contextual cueing task, a local processing strategy is usually advantageous without observers needing to use global processing. So, is it possible to adapt the contextual cueing in being a purely global processing task, by directing attention to global but not to local cues? Inspired by Olson and Chun’s (2002) study one could design an experiment in which the global configuration, but not the local one, was *consistently* repeated across trials, so that attention to and encoding of the non-local cues would result in a reaction time benefit, whereas attention to the local cues would not. It will also be interesting to find out whether the contextual cuing task of intermediate coherence scenes (experiment 2) is a local or a global processing task, given that the hit rate of recognition is only slightly higher than that of non-scene stimuli (around 50%) and much lower to those of full coherence scene stimuli (experiment 3).

Certainly, one timely need for future research is the investigation of novelty aversion in autism as this behavior has been clinically observed but not studied in

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research (U. Frith, 2008, personal communication). In the present thesis, some novelty effects in the form of increased reaction time in the novel trials have been reported. It is not clear what aspect of the stimuli adversely affected search time in autism, but it would be interesting to find out whether novelty aversion reflects top-down modulation atypicalities and also how it correlates with the clinical symptoms in autism and in particular with the symptom of insistence on sameness. Novelty effects can also be seen in the realistic scene stimuli, but since these were also observed in the TD group, one factor could pertain to the increased stimulus complexity that scene stimuli have compared to the letter stimuli.

To date, there are no developmental studies on implicit learning in autism and these are needed since autism is a developmental disorder whose signs and symptoms change with time. Now, that the behavioral studies on implicit learning in autism are accumulating, the time is ripe for neuroimaging studies to shed light in exploring whether people with ASD activate the same brain areas as the control group, while performing an implicit learning task. Indeed, preliminary evidence from two different groups of research, reveal that although the ASD group shows learning equivalent to the control group, they do not employ the same brain areas as a control group does (Barnes, 2008; Travers, Klein, Klinger, Klinger, & Kana, 2009).

Additionally other areas of strengths in autism, such as those pertaining to memory, have been very little investigated. Of the six recognition tests employed in this thesis and which assessed observers' memory of the repeated trials, only one revealed superior performance from the ASD group. Although, it is difficult to sustain that memory was indeed superior rather than an artefact of the slower visual search in ASD, future research should investigate whether memory for repeated material is indeed enhanced under conditions in which recognition can occur very



fast. It would also be interesting to explore whether superior memory of repeated material was related to the diagnostic feature of a preference for sameness and regularity.

### 6.7. Implications of Findings

The intact implicit learning of spatial context that has previously been shown in children with ASD was replicated with ASD individuals in adolescence and adulthood. However, some of the experiments presented in this thesis show sensitivity to the local cues either compared to non-local cues or compared to global cues. It is likely that previous studies did not replicate this sensitivity, because their design did not encourage such attention to local cues. It is also likely, that this sensitivity may be more prominent in the present thesis, not only because the design was such that either encouraged local processing, but also because older ASD individuals were examined and so their greater degree of practice and experience may have enhanced their local processing skills (but see Pellicano et al., 2006).

Implicit learning in autism has not been studied extensively and therefore its contribution to education has not been prominent. Uta Frith (2003) supported that able children with Asperger's syndrome are often able to acquire knowledge about the social world, through explicit learning strategies such as reading books and searching in the internet, as a way to compensate for what they could not learn in an implicit manner. Now, given that the finding of a preserved ability to learn implicitly is replicated by several studies, the time seems ripe to start incorporating the concept of implicit learning in our understanding of how people with autism can learn about the world and in the development of effective programs. In their discussion of how teaching can be effective, Blakemore and Frith (2005, p. 141) have put forward some questions that are valuable for teaching people with autism too: "*When can explicit*

*teaching replace implicit teaching? Is a degree of prior implicit learning always helpful? Is it possible that a reciprocal dialectic between implicit learning and explicit teaching most efficiently supports learning”.*

In some subjects, explicitly teaching conceptual knowledge, through the use of textbooks and formal classes is the only teaching method that can be used. However, some subjects require the opportunity of hands-on experience that allows skill learning to take place. Although this hands-on skill learning may be more beneficial than teachers explaining rules and knowledge, not everything that needs to be learned can be taught implicitly. But, even for those subjects, some prior implicit learning may be helpful. Indeed, it has been suggested that teaching something implicitly (e.g. giving good examples of a category) and then providing more explicit instructions can be a very effective way of learning (Sun, Mathews, & Lane, 2007). More specifically, the same authors support that the synergy between implicit and explicit learning, can aid performance when it is acquired somehow separately, as in the example above, before it is integrated. Perruchet (2008) points to the need for future studies to increase the practical implications of implicit learning in education, which have been sparse partly because research tends to focus on studying implicit and explicit learning independently while in real-world situations these two processes interact.

The findings of the present thesis are confined to only one aspect of implicit learning that relates to an ability to detect and encode regularities in a spatial context. However, most forms of implicit learning are about learning what repeatedly covaries in the environment and this learning is of great ecological significance, because it reduces complexity in a continuously changing sensory environment and also implicit learning itself is a powerful mechanism because it is durable over time, robust over interference and exhibits high capacity (Chun & Jiang, 1999; Reber, 1989). Thus,

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although social skills interventions and well-known treatment programs are developed with the aim of explicitly teaching a set of rules (Klinger et al., 2007), we should attempt to develop programs that make use of the special abilities of people with autism and that are based on the assumption that implicit as well as explicit operations should be combined to promote learning in autism. For instance, if intact implicit learning extends to tasks using social stimuli then this would indicate the effectiveness of interventions that are based on a covert promotion of invariant relationships between social cues and context (Brown & Plaisted, 2008).

Although previous studies have failed to find correlations between the clinical characteristics and performance in these tasks, it is possible that the present finding of a sensitivity to the local context may be the outcome of restrictiveness and narrowness. Insofar as it is, interventions could aim to reduce the narrowness. But, it is also possible that instead of trying to teach people with autism our ‘typical’ behaviors, interventions could help them succeed in real-life by making use of their particular strengths. For instance, Brady and Chun (2007) suggest that focusing attention and encoding of the local context is an adaptive behavior because it reduces complexity. This is not to say that interventions should not aim to alleviate the symptoms of autism, but that instead of trying to teach people with autism to perform ‘typically’ they should also aim to utilize the strengths and skills of people with autism and maybe the outcomes will be more positive.

### 6.8. Closing Summary

Successful performance on the contextual cueing task is based on the ability to encode the repeated context and associate it with the location of its target. As highlighted in Chapter 5, it is not well known exactly how associative learning occurs, but two cognitive operations must be preserved in order to achieve contextual cueing. Firstly,

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an ability to integrate the distractor items with the target in order to encode the repeated context. Secondly, top-down attentional guidance, so that activation of the memory for the repeated context can lead to faster target localization in trials that repeat. Top-down modulation and the ability to integrate features are two interdependent cognitive operations that were considered to be impaired in autism according to the initial formulation of the weak central coherence hypothesis (Frith, 1989, 2003).

The findings of the present thesis that show intact or superior implicit learning of local context in autism are consistent with the recent reformulation of the weak coherence theory (Happé & Frith, 2006) and the enhanced perceptual functioning model (Mottron et al., 2006) that contend an imbalance in the processing of local and global cues, with local cues being more favored by individuals with autism. It remains unclear whether this local processing superiority arises from intact or impaired global processing in autism, because the present tasks did not test these processes independently. However, there was an indication that local learning was superior to global learning when local and global processing were put in direct competition in a single experiment.

Thus, the present thesis does not distinguish whether global processing is reduced or just is not the preferred way of processing information for ASD individuals, but adds to the existing literature about the local processing superiorities in autism. The important implication of this thesis is that it opens a new way for understanding how the special skills of people with autism can be exploited to support their implicit learning and therefore their education needs...and this is an exciting development!

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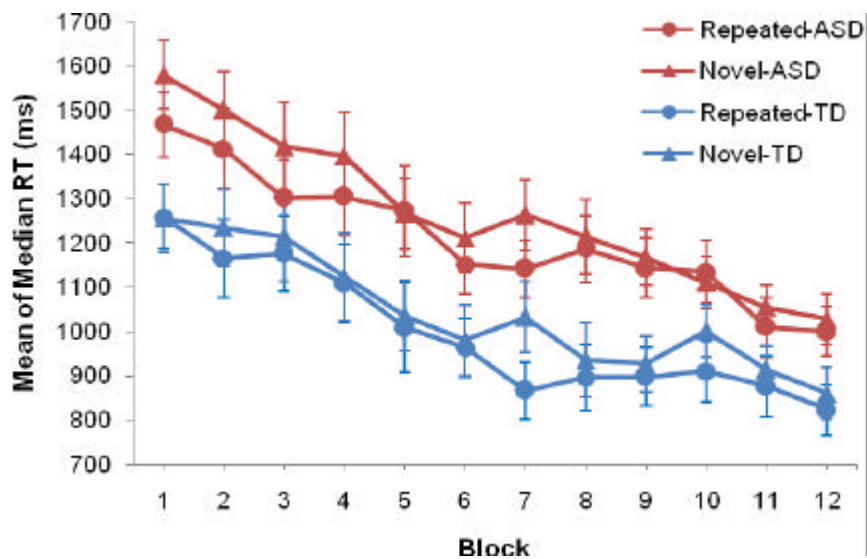
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## 8. APPENDICES

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### Appendix 2.1.

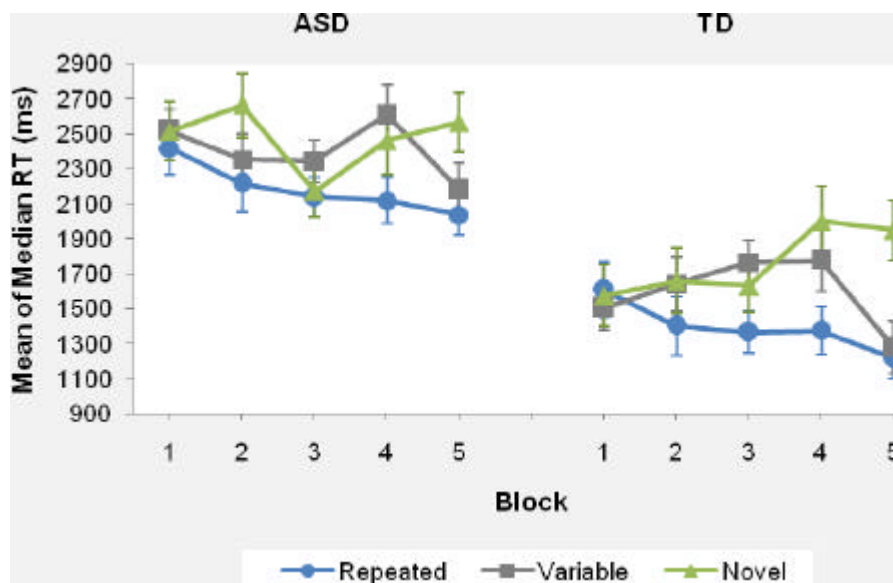
Mean of median reaction time (in milliseconds) across the two conditions as a function of block and group.



## Appendices

### Appendix 3.1.

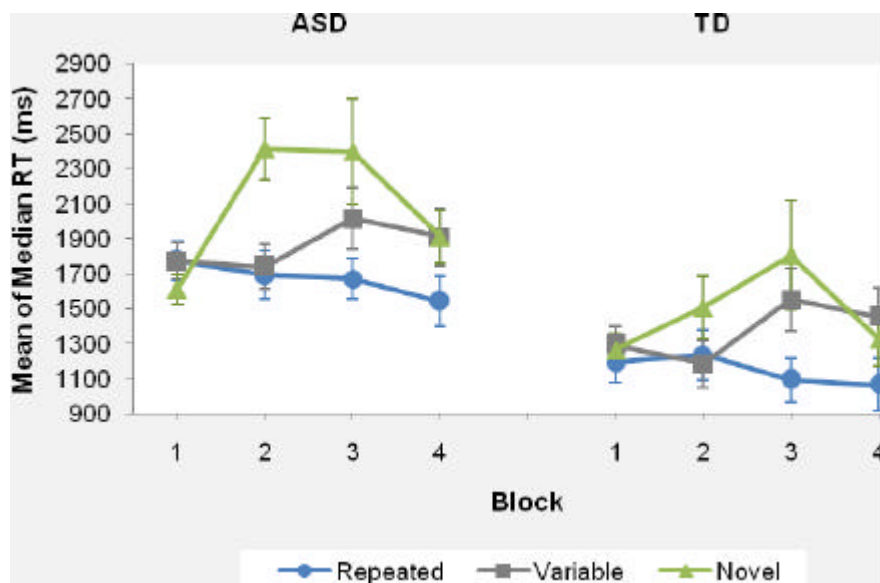
Mean of median reaction time (in milliseconds) across the three conditions as a function of block and group from Experiment 3.



## Appendices

### Appendix 3.2.

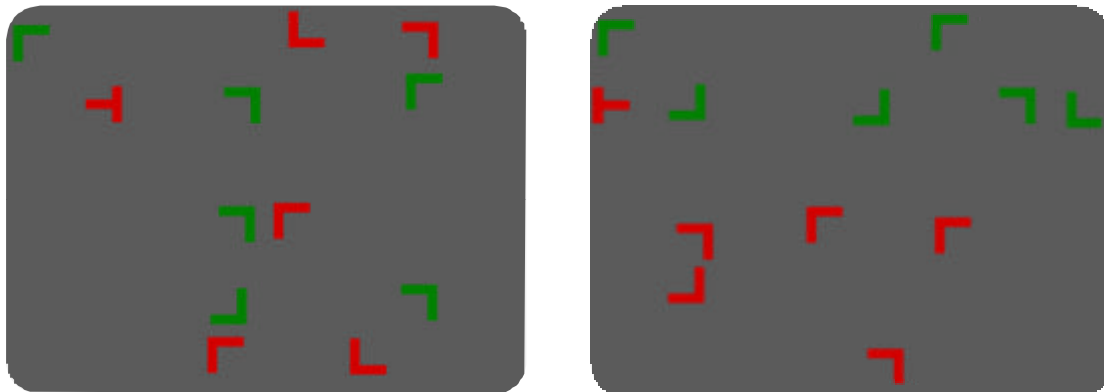
Mean of median reaction time (in milliseconds) across the three conditions as a function of block and group, from Experiment 2.



## Appendices

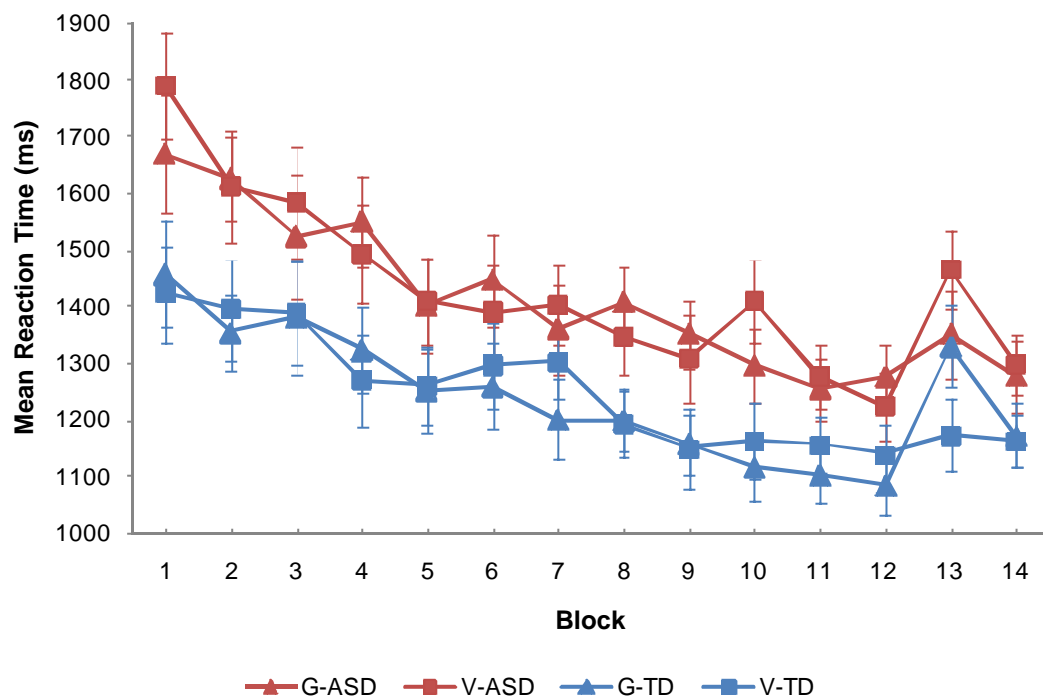
### Appendix 4.1.

Example stimuli of the ‘random non-local context’ (left panel) and the ‘half non-local context’ displays (right panel) used in Experiment 5. In the random non-local context condition, the location of a particular color on the display is randomly selected, while in the half non-local condition, the distribution of the colors create a green and a red group of items.



Appendix 5.1.

Mean reaction time (in milliseconds) across the global context (G) and very local context (V) conditions as a function of block and group. Illustrated in this figure are the training phase (blocks 1 to 10) as well as the repeated trials (blocks 11 and 12) and novel trials (blocks 13 and 14) of the transfer phase.



## Appendices

### Appendix 6.1.

Average response time (standard errors) as a function of group, condition and epoch, for Experiments 1, 2 and 3.

EXPERIMENT	CONDITION	GROUP			
		ASD		TD	
		Epoch 1	Epoch 2	Epoch 1	Epoch 2
1	Repeated	1318 (84)	1103 (78)	1113 (58)	878 (37)
	Novel	1395 (92)	1140 (73)	1141 (56)	945 (34)
2	Repeated	2320 (142)	2078 (114)	1508 (146)	1300 (118)
	Variable	2436 (126)	2395 (130)	1576 (130)	1530 (134)
	Novel	2589 (152)	2514 (144)	1620 (156)	1978 (149)
3	Repeated	1735 (113)	1609 (126)	1207 (116)	1083 (130)
	Variable	1760 (107)	1965 (159)	1280 (111)	1506 (164)
	Novel	2015 (114)	2156 (210)	1391 (117)	1569 (217)

## Appendices

### Appendix 6.2.

Average response time (standard errors) as a function of group, condition and epoch, for Experiments 4, 5 and 6.

EXPERIMENT	EPOCH	CONDITION					
		G-ASD	L-ASD	V-ASD	G-TD	L-TD	V-TD
4	1	1389 (48)	1416 (55)	1394 (45)	1373 (93)	1381 (66)	1363 (76)
	2	1344 (48)	1390 (51)	1398 (67)	1274 (72)	1281 (66)	1283 (72)
	3	1362 (54)	1332 (54)	1280 (55)	1212 (67)	1268 (70)	1224 (72)
	4	1319 (56)	1342 (46)	1322 (48)	1191 (73)	1230 (58)	1176 (56)
	5	1277 (48)	1322 (51)	1245 (50)	1196 (54)	1247 (70)	1164 (62)
	Repeated	1142 (40)	1211 (41)	1177 (41)	1077 (39)	1112 (40)	1089 (40)
	Novel	1273 (37)	1314 (52)	1304 (44)	1135 (36)	1153 (51)	1143 (43)
5		G-ASD	R-ASD	H-ASD	G-TD	R-TD	H-TD
	1	1398 (58)	1431 (62)	1486 (55)	1251 (58)	1253 (62)	1305 (55)
	2	1364 (57)	1416 (60)	1337 (60)	1189 (57)	1216 (60)	1295 (60)
	3	1337 (56)	1344 (65)	1322 (66)	1175 (56)	1255 (65)	1205 (66)
	4	1283 (58)	1344 (65)	1309 (61)	1149 (58)	1233 (65)	1239 (61)
	5	1220 (53)	1252 (57)	1314 (60)	1112 (53)	1149 (57)	1148 (60)
	Repeated	1159 (41)	1154 (49)	1192 (51)	1048 (41)	1052 (49)	1021 (51)
	Novel	1231 (42)	1192 (48)	1181 (49)	1090 (42)	1101 (48)	1034 (49)
6		G-ASD	V-ASD	G-TD	V-TD		
	1	1647 (78)	1701 (89)	1406 (71)	1408 (81)		
	2	1537 (87)	1539 (86)	1352 (79)	1329 (78)		
	3	1424 (78)	1399 (77)	1256 (72)	1278 (70)		
	4	1383 (64)	1373 (63)	1200 (59)	1247 (57)		
	5	1323 (56)	1359 (74)	1137 (51)	1155 (67)		
	Repeated	1264 (52)	1250 (55)	1093 (48)	1147 (50)		
	Novel	1313 (61)	1381 (57)	1251 (56)	1168 (52)		